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Document 20.2
LLNL Radiological Safety Program for Radioactive Materials

Recommended for approval by the ES&H Working Group

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New document or new requirements

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☐ **New document**
☒ **Major requirement change**

Revision 2

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20.2

LLNL Radiological Safety Program for Radioactive Materials*

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* **Major revision**

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LLNL Radiological Safety Program for Radioactive Materials

1.0 Introduction

The Department of Energy's (DOE's) rule on occupational radiation protection (10 CFR 835, Rev. 1, hereafter referred to as the "Rule") requires specific controls for work with radioactive materials. This document contains requirements and best management practices that pertain specifically to radioactive material handling. The programmatic organization or the Environment, Safety, and Health (ES&H) Team health physicist may specify additional controls, as necessary. Requirements are presented as "shall" statements, and best management practices are presented as "should" statements. Appendix A contains the definition of "shall," "should," and other terms used in this document.

When implemented in conjunction with Document 20.1, "Occupational Radiation Protection," in the *ES&H Manual*, this document provides a basic level of radiation protection. Alternate methods of implementing the requirements of this document shall be reviewed by the ES&H Team health physicist and approved in a safety plan. They shall also be consistent with the document *LLNL's Radiation Protection Program* (RPP) and the as low as reasonably achievable (ALARA) process described in Document 20.4, "LLNL Occupational Radiation Protection ALARA Program," in the *ES&H Manual*. Deviations from this document shall be approved following the process contained, Document 3.2, "Safety Basis Thresholds," in the *ES&H Manual*.

This document does *not* apply to:

- Background radiation (including consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation).
- Radiation doses received as a patient for the purposes of medical diagnosis or therapy.
- Radiation doses received from participation as a subject in medical research programs.
- Use or possession of commercially available items and articles that either
  - Contain Nuclear Regulatory Commission- (NRC-) exempt quantities of radioactive material.
  - Are generally licensed by the NRC. However, such items shall be controlled in accordance with the provisions of the NRC license (see Section 3.1).

2.0 Hazards

Work with radioactive materials could result in:

- An external radiation dose to individuals entering radiologically controlled areas.
- An internal radiation dose from inhalation, ingestion, absorption through the skin, or injection (via a cut). Intakes of submilligram quantities of transuranics (e.g., plutonium and curium) can cause radiation doses on the order of hundreds to thousands of rems.
- External contamination of workers. If a worker is contaminated with radioactive material, prompt decontamination will minimize the dose and prevent the spread of contamination. Radiation dose can occur through direct irradiation of living tissue beneath the outer layer of skin, internal deposition resulting from ingestion or inhalation, or absorption through broken or unbroken skin.
- The contamination of work areas or facility equipment (e.g., the ventilation system), possibly resulting in program delays and expensive clean-up costs.
- Generation of radioactive waste. To minimize these hazards and ensure that radiation doses are kept as low as reasonably achievable, individuals who work with radioactive materials shall adhere to the requirements and controls specified in Sections 3.0 and 4.0 of this document.

3.0 Controls

This section contains controls for acquiring, transporting, and working with radioactive materials. The following appendices contain supporting information:

- Appendix B contains a summary of the controls in this document.
- Appendix C contains procedures for personnel decontamination.
- Appendix D contains the surface contamination values for defining Contamination Areas and determining if contaminated items shall be controlled and handled as radioactive material.
- Appendix E contains the radioisotope-specific thresholds for Class III and IV sealed radioactive sources. The threshold for Class III sealed sources is also used to determine transportation and area posting requirements. In these cases, the values apply to both sealed and dispersible radioactive material.

3.1 General Information

Radioactive materials in excess of the Class III, Appendix E values shall be used and stored in a Radioactive Materials Area (RMA). Smaller quantities of radioactive material may be used and stored in areas other than an RMA with the approval of the facility manager and the concurrence of the ES&H Team.

Within an RMA, specific workplaces for radioactive material are categorized as Type 0, I, II, and III, depending on the level of contamination control they provide:

- A Type 0 workplace (e.g., a shelf or storage cabinet) provides no specific protection for the worker or the area.
- A Type I workplace (e.g., a laboratory benchtop) provides minimal protection.
- A Type II workplace (e.g., a chemical fume hood) provides one barrier between the material and the worker and a moderate level of protection.
- A Type III workplace (e.g., a glovebox) provides two barriers between the material and the worker and a high level of protection.

The relationship between RMAs and various types of workplaces is shown in Fig. 1. The ES&H Team health physicist is responsible for determining the type of workplace necessary for an operation (or conversely, the types of operations that can be conducted or the maximum amount of material that can be handled in a given workplace).

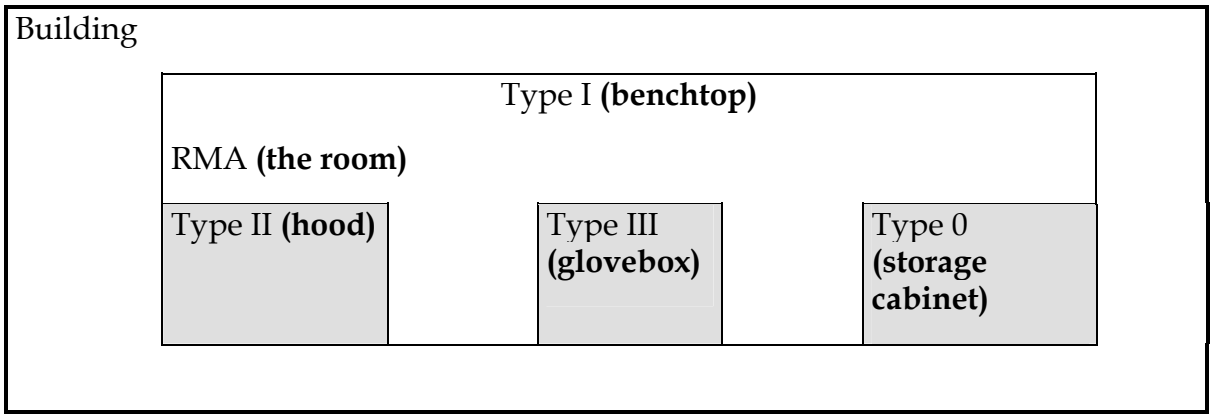

Figure 1. Relationship between RMAs and Type 0, I, II, and III workplaces.

Barriers have varying degrees of structural integrity and may include a metal can, a plastic bag, or the negative airflow of a chemical fume hood. If an operation (e.g., vibration or shock testing) could potentially breach a containment barrier, then

additional packaging or containment requirements may be necessary to provide a safe work area or to protect the environment.

3.1.1 NRC Licensed Items and Articles

The NRC controls the production and dissemination of commercially available items and articles that contain radioactive material (e.g., smoke detectors, lead-based paint analyzers, static eliminators, tritiated exit signs, soil density gauges, x-ray fluorescence analyzers, and explosives detectors). Companies that produce such items and articles shall have a specific license; individuals or organizations that acquire these products shall do so under the provisions of either a general license or a specific license, unless the amount of radioactivity in the item or article is less than the exempt quantities identified in 10 CFR 30.71. A general license is automatically bestowed upon acquisition of certain items or articles that have more radioactivity than specified in 10 CFR 30.71. LLNL is legally obligated (by the LLNL RPP) to abide by the provisions of the general license, which usually requires:

- Labeling.
- Use of the items or articles in accordance with the manufacturer's instructions.
- Limitations on disposal.
- Periodic leak tests (depending on the amount and form of radioactivity involved).

A specific license is required for items or articles that exceed the exempt quantities listed in 10 CFR 30.71 and are not generally licensed by 10 CFR 31.5. (Manufacturers may not ship items that require a specific license to individuals or organizations that do not have a specific license, or equivalent.) Because LLNL is a DOE facility, LLNL does not have a specific license; however, the Materials Management Section (of the Mechanical Engineering Department) has an identification number that allows the acquisition of specifically licensed items. Items and articles requiring a specific license shall be handled in accordance with Document 20.1 and this document.

Commercially available items and articles containing NRC-exempt quantities of radioactive material (e.g., welding rods and lantern mantles):

- Do not have to be acquired as radioactive material (i.e., may be purchased via the UniCard system).
- Do not have to be authorized with an Integration Work Sheet (IWS).

- Shall retain the labels provided by the manufacturer but do not have to be otherwise labeled or controlled as radioactive material once they arrive onsite.
- Shall be transported offsite in accordance with Department of Transportation (DOT) regulations.

  Note: NRC-exempt quantity items may or may not be regulated for transportation. Contact the Materials Management Section for guidance.
- Shall be used in accordance with the manufacturer's instructions (otherwise, it shall be handled as radioactive material in accordance with LLNL requirements).
- Are outside the scope of 10 CFR 835.

Commercially available items and articles that are generally licensed by the NRC:

- Shall be acquired as radioactive material (see Section 3.3). If the individual acquiring the item or article is unaware that it contains radioactive material until after it is delivered, he/she shall contact the Materials Management Section and the ES&H Team and request that the
  - Normal receipt surveys be conducted.
  - Item is entered into the accountability system, if appropriate.
- Shall be used in accordance with the manufacturer's instructions; otherwise, the general license is void, and the item shall be handled in accordance with LLNL requirements.
- Shall retain the labels provided by the manufacturer.
- Shall be entered into the LLNL sealed source accountability system as Class II sealed sources if the general license requires them to be periodically inventoried or leak tested. An example is nongaseous sources exceeding the exempt quantities specified in 10 CFR 30.71 and containing more than 100 μCi of beta/gamma emitting radionuclides or 10 μCi of alpha emitting radionuclide.
- May be used by individuals that are not trained as radiation workers.
- May be transported onsite by the user but shall be transported offsite under the control of the Materials Management Section.

Subcontractors and vendors may bring onsite (and use) radioactive sources that contain less activity than the Class III values in Appendix E. Specific notification of the program or the ES&H Team is not required. A Procured Services Work Sheet (PWS) is required

before a subcontractor or vendor is authorized to bring onsite (or use) a radioactive source that contains more activity than the Class III values in Appendix E, unless the source is a commercially available item or article (see Section 3.1.1). The subcontractor or vendor is responsible for following the applicable DOT regulations while transporting the material offsite but is not required to process the radioactive material through the Materials Management Section. (As a courtesy, the Materials Management Section provides shipping support for a vendor's radioactive material for either receipt onsite or shipment offsite.)

3.2 Written Authorizations and Safety Plans

A written authorization [e.g., an Integration Work Sheet (IWS)] is required:

- For use or storage of radioactive material exceeding background levels (excluding nominal amounts of radioactivity contained in consumer products).
- To control entry into and to perform work within Radiological Areas (e.g., Contamination/High Contamination Areas, Airborne Radioactivity Areas, Radiation/High Radiation Areas).

The IWS should include the controls necessary to ensure that radiation doses are kept as low as reasonably achievable, and that the contamination is properly controlled [e.g., with personal protective equipment (PPE), turn-back or hold points, and supplemental dosimeter requirements].

A facility safety plan (FSP) or Integration Work Sheet/safety plan (IWS/SP) is required:

- For the following activities, unless the authorizing individual and the E&SH Team health physicist jointly determine that a safety plan is not necessary.
  - Work in Type I, II, and III workplaces.
  - Use of Class IV sealed radioactive sources.
- To document alternate methods of implementing the requirements in this document.

Document 3.3, "Facility Safety Plans and Integration Work Sheets with Safety Plans," in the *ES&H Manual* contains detailed guidance for preparing safety plans.

A lifecycle plan is required before beginning an operation that is likely to generate radioactive waste. This plan shall be drafted and implemented in accordance with Radioactive and Hazardous Waste Management Procedure WIC 117, *Life-Cycle Planning*, and is required to:

- Ensure the safe management of radioactive waste from the time of generation to disposal.
- Determine whether a path to disposal exists.
- Ensure that the requirements of DOE Order 435.1 and DOE M 435.1-1 are met.

3.3 Acquisition of Radioactive Materials

The Hazards Control Department's RPP subject-matter expert (RPP-SME) shall approve the acquisition of radioactive materials whether purchased, borrowed, or provided by others (e.g., other DOE contractors, universities, or companies). Radioactive materials may not be purchased using a Procard.

Note: These requirements *do* pertain to items and articles generally licensed by the NRC. They do *not* pertain to non-DOT regulated material (i.e., where the radioactivity level is less than 2 nCi/g) or commercially available items and articles containing NRC-exempt quantities of radioactive materials.

Radioactive materials that are not DOT regulated may be shipped directly to the requesting individual without being processed by the Materials Management Section. However, if the quantity of radioactive material exceeds LLNL's threshold for radioactive material labeling, the receiver shall ensure the item is labeled and controlled as radioactive material.

Controls for the acquisition of radioactive material are summarized in Table 1.

The requesting individual shall provide the proper delivery address to the sender and, if dealing with intermediaries such as purchasing agents, identify the hazards associated with the material (e.g., radioactive or otherwise). All radioactive material shall be delivered to the following address:

Lawrence Livermore National Laboratory
Materials Management Section
Building 231 Vault
For: [Provide Name of Requesting Individual]
7000 East Avenue
Livermore, CA 94550

Table 1. Controls for acquisition of radioactive material.

Type of radioactive material	Regulated by		LLNL Controls		
	NRC?	DOT?	Acquire as rad?[1]	Process by MM?[2]	Label/ control as rad?
Low-level samples not regulated by DOT	No	No	No	No	If > 1 nCi
Commercially available items and articles that contain NRC-exempt quantities of radioactive material	No	Maybe	No	If DOT-regulated	Yes: manufacturer's labels
Commercially available items and articles generally-licensed by the NRC	Yes	Yes	Yes	Yes	Yes: manufacturer's labels; leak tests
Other radioactive materials	Yes	Yes	Yes	Yes	Yes

[1] "Acquire as rad" means the RPP-SME shall approve the acquisition and the material may not be purchased using a Procard, and the material shall be delivered to the Materials Management Section (B231 Vault).

[2] MM = Materials Management

Upon receipt of packages from offsite, Receiving and Distribution shall promptly notify the Materials Management Section of items that are labeled as radioactive. The Materials Management Section shall transfer the package to the Building 231 vault, conduct the receipt surveys, and ensure the item is properly labeled and entered into the accountability system. The Materials Management Section shall then deliver the radioactive material to the ES&H Team health and safety technician at the requesting facility.

According to DOT regulations, packages that contain low levels of radioactive material may be shipped without external marking or labeling. However, the package will contain a piece of paper that identifies the radioactive contents. If Receiving and Distribution delivers such a package directly to a facility, the individual that opens the package shall promptly notify:

- The ES&H Team health and safety technician, who will survey the item and ensure it is properly labeled.
- The Materials Management Section, which will enter the item into the accountability system.
- The facility manager.

3.4 Posting and Labeling

General posting requirements are contained in Document 20.1; specific guidance for posting is contained in the *Radiation Safety Sign Manual*. Posting requirements that pertain exclusively to radioactive materials are presented in this section.

3.4.1 Radiologically Controlled Areas

A radiologically controlled area is any area where access is managed to protect individuals from exposure to radiation or radioactive materials. Each access point to a controlled area that is not a Radiological Area shall be posted using either a CAUTION Radioactive Materials Area or a CAUTION Radiological Buffer Area sign.

The CAUTION Radiological Buffer Area sign may be used to post areas of the facility (e.g., change rooms and hallways connecting RMAs) where there is a potential for contamination, but where radioactive material handling is not specifically authorized. If the Radiological Buffer Area sign is used, the Radioactive Materials Area sign is still required at the access point to the RMA. Individuals entering the controlled area shall have completed General Employee Radiological Training [GERT] within the previous 24 months or be escorted by a GERT-trained worker.

3.4.2 Radioactive Material Areas

Each access point to an RMA shall be clearly and conspicuously posted with a CAUTION Radioactive Material Area sign if either of the following conditions exist:

- The total amount of radioactive material exceeds the Class III values provided in Appendix E.
- The area contains Type I, II, or III workplaces with more than 1 μCi of dispersible radioactive material.

The access point to an RMA meeting the above criteria does not need to be posted if any of the following conditions exist:

- The area is posted with a CAUTION Radiation Area, CAUTION Contamination Area, CAUTION Airborne Radioactivity Area sign, or variations of these signs.
- Each item or container of radioactive material is labeled in accordance with this document so that individuals entering the area are made aware of the hazard.
- The radioactive material of concern consists solely of structures or installed components that have been activated (e.g., as might exist in a high-energy accelerator facility).

- The area contains only packages received from offsite radioactive material transportation that are labeled and in a non-degraded condition. These areas do not need to be posted until receipt surveys are conducted.

If the radioactive material is in several areas of the room (e.g., in a high bay or machine shop), the door to the area should be posted as an RMA. However, if the radioactive material is located only in a localized area of the room (e.g., in a cabinet), the cabinet door may be posted (as opposed to the door to the room).

3.4.3 Radioactive Material-Handling and Storage Areas

Within an RMA, designated radioactive material handling and storage areas (i.e., Type 0, I, II, and III workplaces) shall be specifically identified and posted with a CAUTION Radioactive Material sign (preferably) or the radiation trefoil symbol.

3.4.4 Radiological Areas

Each access point to a Radiological Area (i.e., a Radiation Area, High Radiation Area, Very High Radiation Area, Contamination Area, High Contamination Area, and Airborne Radioactivity Area) shall be clearly and conspicuously posted as specified in the *Radiation Safety Sign Manual*. The definition of these terms is contained in Appendix A.

3.4.5 Radioactive Materials and Contaminated Items

Each item or container of radioactive material, including contaminated items and equipment containing radioactive material, shall bear a durable, clearly visible label with the radiation trefoil symbol and the words CAUTION Radioactive Material or DANGER Radioactive Material. The DANGER label should be used if uncontrolled access to the item could result in overexposures of workers. The label shall provide sufficient information (e.g., the isotope and the amount of radioactivity) to permit individuals handling, using, or working in the vicinity of the items or containers to take precautions to avoid or control exposures.

Labels may be obtained from the Materials Management Section or the ES&H Team. Items and containers may be excepted from the LLNL radioactive material labeling requirements if any of the following conditions exist:

- Surface contamination values are less than the values in Appendix D and the item or container does not otherwise contain 1 nCi or more of radioactive material.

- The total amount of radioactive material (excluding surface contamination) is less than 1 nCi. Items with more than 1 nCi but less than 1 μCi need only be labeled with the radiation trefoil symbol.
- The item or container is any of the following
  - Used, handled, or stored in areas posted and controlled as specified in this document, and sufficient information is provided to permit individuals to take precautions to avoid or control exposures.
  - Packaged, labeled, and marked in accordance with DOT regulations or DOE orders governing radioactive materials transportation.
  - Inaccessible, or accessible only to individuals authorized to handle or use them or to work in their vicinity.
  - Installed in manufacturing, process, or other equipment such as piping and tanks.
- The radioactive material consists solely of
  - Nuclear weapon components.
  - Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation.
- The item is a commercially available product labeled by the manufacturer in accordance with NRC regulations.

Sealed Radioactive Sources. Labels for sealed radioactive sources shall indicate the radionuclide, the amount of radioactivity as of a specified date, the hazard classification (Class I, II, III, IV), and should indicate the source custodian's name. Class IV sealed sources shall have all information, except for the source custodian's name, on a metal tag. Radioactive material labels applied to sealed radioactive sources or to the source containers may be excepted from the color specifications otherwise required by the Rule.

Samples for radioactive materials analysis. Until determined to be radioactive, samples, swipes, and filters collected for analysis do not need to be labeled so long as they remain in the custody of appropriately trained and knowledgeable personnel (e.g., the sample collector or a radiation worker).

3.4.6 Radioactive Materials Management Areas

A Radioactive Materials Management Area (RMMA) is an area where there is a possibility of generating mixed (hazardous and radioactive) waste (e.g., RMAs containing a Type I, II, or III workplace, or areas around high-energy accelerators that produce activation products). An RMMA sign should be posted at the main entrance to the area and may be combined with the Health Hazard Communication Poster.

Note: Administratively designating an area as an RMMA is part of the Waste Moratorium agreement between LLNL and DOE and pertains to waste disposal only; it is not a safety sign.

Hazards Control maintains and distributes the list of RMMAs. Programmatic organizations are responsible for notifying the ES&H Team health physicist if an area is incorrectly listed or posted.

3.5 Personal Protective Equipment

PPE requirements for radiological work areas vary, depending on area conditions and the work to be conducted. Protective clothing is required for entry to airborne radioactivity areas and areas where removable contamination exists at levels exceeding the removable surface contamination values specified in Appendix D of this document. The ES&H Team health physicist is responsible for identifying the appropriate level of PPE and may increase or decrease the PPE requirements as area conditions change. PPE requirements should be posted at the access point to the area requiring PPE.

Note: Changes to PPE requirements explicitly stated in a safety plan shall be approved by the individual who originally approved the plan or his/her designee.

Any special clothing shall be furnished by the program, except in emergencies when Hazards Control may supply the needed PPE. More information on PPE can be found in Document 11.1, "Personal Protective Equipment," in the *ES&H Manual*.

A buttoned lab coat with long sleeves, waterproof gloves, and closed-toe shoes are required for work in Type I, II, and III workplaces, unless otherwise specified by the ES&H Team health physicist. Sandals or perforated shoes are not permitted. Depending on the operation, eye protection may also be required for work in Type I and II workplaces. PPE should not be worn in general office areas or public areas (e.g., rest rooms or cafeterias) but may be worn in the halls while going from one room to another (e.g., between laboratories). Contaminated PPE should be promptly replaced.

Respiratory protection (including air-purifying half-mask and full-face respirators, supplied-air, and self-contained breathing apparatus) may be required when dispersible radioactive materials are handled and engineered controls are not feasible, or during emergency conditions. Work should be planned so that prolonged use of respirators is not necessary. Respirators are available from the ES&H Team; however, users are required to have a current respirator card and a hazards assessment. Information on obtaining and using respiratory protection can be found in Document 11.1.

Use of respirators can impact the worker's ability to perform work safely. For example, respirators usually impede clear communication and peripheral vision, and may result

in the job taking longer to accomplish, which in turn may result in the worker receiving additional external dose. Respirators should be chosen based on the protection factor and actual or potential airborne radioactivity levels, taking into account ALARA considerations, other industrial hazards, and worker safety. The ES&H Team health physicist is responsible for determining when respirators are an appropriate component of PPE. Although the threshold for respiratory use may vary significantly, respirators are typically not necessary when the amount of contamination on an item or article is less than 0.1% of the Class III values listed in Appendix E of this document. If respirators are prescribed because an activity has the potential of generating significant airborne activity, all workers in the potential exposure area shall wear a respirator, even if they are not directly involved in the work.

Work performed in areas containing atmospheres that may be immediately dangerous to life or health (IDLH) requires equipment that is properly designed and used. Under no circumstances shall any such work begin without the review and concurrence of ES&H Team.

3.6 Free Release of Items from RMAs

"Free release" of an item means it is released from an area for unrestricted use. The controls for free releasing items from an RMA increase as the likelihood of the item being contaminated increases. The individuals authorized to free release various types of items from an RMA are identified in Table 2, along with the type of survey required. If the item is not transferred from the RMA promptly after being surveyed, it shall be protected from cross contamination or resurveyed prior to its transfer.

Radioactive material shall not be free released (unless it is non-DOT regulated or a commercially available item containing an exempt quantity of radioactive material). Other materials and equipment shall be controlled as radioactive material if any of the conditions below exist:

- The item contains 1 nCi or more of radioactive material (excluding surface contamination).
- Surface contamination levels on accessible surfaces exceed the values specified in Appendix D of this document.
- Prior use suggests that the surface contamination levels on inaccessible surfaces are likely to exceed the values specified in Appendix D of this document.

Table 2. Controls for free-release of items from an RMA.

Authorized individuals	Authorized activity	Type of survey required
Responsible Individual (as defined in the applicable safety plan) or Radiological worker	May free release items that • Have *not* been associated with the radiological work area and • Are *not* suspected of being contaminated. [1]	No survey required.
Radiological worker or ES&H Team health and safety technician	May free release items that • Have been associated with a Type I or II workplace and • Are *not* suspected of being contaminated. [1]	A direct survey using the appropriate meter, and a wipe survey evaluated on a hand-held detector.[2] • Survey documentation is not required. • Wipes of low-energy beta emitters shall be evaluated on a Liquid Scintillation Counter (LSC) or equivalent.
ES&H Team health and safety technician or Other workers specifically trained and authorized to conduct this task	May free release items that are suspected of • Being externally, internally, or volumetrically contaminated[3] or • Having induced radioactivity[4]	A documented[5] radiation and contamination survey.

1 Items in an RMA (e.g., chairs and computers) are generally not suspected of being contaminated unless they have been associated with radioactive material or the radiological work area. [NOTE: In some facilities, (e.g., the Plutonium Facility), all items in the RMA may be considered potentially contaminated.]

2 A wipe survey is not required if a thorough direct survey is conducted and no activity above background is detected. If activity above background is detected on either the direct or wipe survey, the item is suspected of being contaminated and shall be released by an ES&H Team health and safety technician or controlled as radioactive material.

3 Items in an RMA are suspected of being contaminated if they
- Are being removed from a posted Contamination Area, High Contamination Area, Airborne Activity Area, or a contaminated workplace. Items may also be suspect if they are removed from a Buffer Area established for contamination control purposes.
- Have been used directly with radioactive material (e.g., beakers, ducting, or vacuum pumps associated with contaminated systems).
- Are being removed from a potential contamination area where the history is not well known.
- Are being removed from a Type III workplace.
- Have been associated with spills of radioactive material.

4 The ES&H Team health physicist shall evaluate items with volumetric contamination or induced radioactivity.

5 The survey shall be documented in accordance with LLNL's *Swipe Manual*.

- The item is activated or volumetrically contaminated.
- The item is a commercially available product generally licensed by the NRC.

Radioactive material may only be conditionally released for onsite transfer from one controlled area to another, as described in Section 3.9.

3.7 Controlling Contaminated Areas

Controls that prevent the inadvertent transfer of removable contamination to locations outside of the contamination area under normal operating conditions shall be maintained and verified. Any area where contamination levels exceed the values specified in Appendix D of this document shall be controlled in a manner commensurate with the physical, chemical, and radiological characteristics of the contaminant and the fixed and removable surface contamination levels.

Areas accessible to individuals where the total surface contamination levels exceed the values specified in Appendix D of this document, but where the removable surface contamination levels are less than the values specified in Appendix D, may be located outside of contamination areas if both the following conditions are met:

- The area is routinely monitored to ensure the removable surface contamination levels remain below the values specified in Appendix D.
- The area is conspicuously marked to warn individuals of its contaminated status.

3.8 Handling Radioactive Materials (including Contaminated Items)

This section contains minimum controls for handling radioactive materials in Type I, II, and III workplaces. The controls in Section 3.8.1 apply to all workplaces and are supplemented by specific controls listed under the heading for each type of workplace. The programmatic organization and the ES&H Team health physicist may identify additional controls. Controls specific to work with fissionable material are specified in Document 20.6, "Criticality Safety," in the *ES&H Manual*.

3.8.1 General Work Controls

- Minimize worker dose and control contamination.
  - Be aware of the external dose rate in the area and the potential for internal dose as a result of an intake.
  - Wear the PPE specified in the safety plan or on postings.

  - Conduct frequent hand surveys. Upon completion of work, survey all potentially contaminated areas of your body (e.g., hands, chest, and forearms). If unexpected levels of activity are found, call the ES&H Team health and safety technician to assist in the removal of contaminated clothing and to conduct a thorough survey. If it is necessary to remove contaminated clothing before the health and safety technician arrives, be careful not to cause contamination of personal clothing or the skin.
  - Minimize the generation of contaminated items or areas.
  - Decontaminate articles or equipment (other than waste) to the lowest practical level, considering economic factors. If the contamination level exceeds the values in Appendix D, the equipment shall be labeled and controlled as radioactive.
  - Conduct frequent surveys of the work area during and upon completion of the work. If unexpected levels of activity are found, or if there is a significant change in the activity level, call the ES&H Team health and safety technician to conduct a thorough survey and ensure the area is properly controlled and posted.
  - Notify the ES&H Team of changes in the workplace that might increase a worker's dose or affect postings.

- Prevent hand or glove damage.

  - Whenever possible and appropriate, use tongs or forceps to handle radioactive materials. Always use tongs, forceps, or other devices to handle items with surface temperatures exceeding 80°C (176°F).
  - Store sharp tools (e.g., scissors, syringes, capillary tubes, or hand tools) in a container that will prevent incidental contact with hands or gloves.
  - Ensure hands and gloves are clear of any machines with moving parts.

- Prevent spills.

  - Tightly close containers that are not in use.
  - Use secondary containment (e.g., a photo tray) when storing and handling liquids.
  - Secure assemblies or containers of radioactive material to prevent spills during an earthquake.
  - If a spill occurs, follow the guidelines in Section 3.11 of this document.

- Use and handle sealed radioactive sources carefully, in a manner commensurate with the hazards and operations involving the sources.

  - Do not carry sealed sources near the body (e.g., in pockets).
  - Do not rub or abrade electroplated sources.
  - Do not breach the source encapsulation.

  - Periodically survey the source or source container for contamination. Call the ES&H Team health and safety technician if removable activity is detected.
  - Visually inspect the source prior to each use. Call the ES&H Team health and safety technician if the source containment appears discolored or degraded in any way.
  - Dispose of, re-encapsulate, or handle as dispersible radioactive material any sealed sources found to be leaking. In all cases, the material shall be controlled in a manner that minimizes the spread of contamination.

- Store material properly.
  - Store radioactive material in an approved cabinet, drawer, or other designated area when not in use. Use a metal or fire-resistant enclosure whenever possible.
  - Do not store sealed sources where they are likely to become contaminated.
  - Store Class IV sources in a locked, fire-resistant cabinet when not in use. Sources installed in equipment are exempt from this requirement.

- Maintain a safe workplace.
  - Ensure the ventilation is functioning prior to starting work each day by checking the flow indicator. Contact the facility point of contact (i.e., the facility coordinator or manager) or the ES&H Team if the ventilation does not appear to be functioning properly.
  - Minimize the amount of combustibles and flammable liquids in the workplace.

3.8.2 Type I Workplaces

- Clearly identify radioactive material work areas from nonradioactive work areas (e.g., by taping down paper, using tape or painted lines to delineate work areas, or posting equipment used to process radioactive materials.)
- If handling liquids, cover the work surface with absorbent paper.

3.8.3 Type II Workplaces

If working in a hood:

- Verify the hood has been flow tested within the previous 12 months by checking the hood sticker. If the hood has not been tested within this timeframe, notify the facility point of contact or the ES&H Team health and safety technician. Do not conduct work in the hood until it has been tested.

- Align the indicator arrows on the sash and sash frame to ensure that there is adequate face velocity.
- Avoid rapid movements and other actions that disturb the airflow (e.g., leaning against the hood's ledge).

If working in other types of enclosures (e.g., a glovebox or equipment shroud), ensure the negative ventilation is operational before beginning work.

3.8.4 Type II and III Workplaces with Local HEPA-filtered Exhaust

- Ensure the ventilation system is functioning prior to starting work each day by checking the differential pressure indicator (e.g., a Magnehelic gauge). Report any anomalies to the facility point of contact or the ES&H Team.
- Check the label on the high-efficiency particulate air (HEPA) filter to verify it has been tested within the last 12 months. Contact the facility point of contact or the ES&H Team health and safety technician if more than 12 months has elapsed since the last test. (HEPA filters installed as housekeeping filters are generally not tested and therefore will not be labeled with a test date. Untested housekeeping HEPA filters do not count as a barrier for the purpose of providing personnel protection or estimating potential offsite dose.)
- Change ventilation system filters only with the assistance of Hazards Control.

3.8.5 Type III Workplaces

- Minimize worker dose.
  - Periodically survey enclosures where radioactive material could build up and create a significant external radiation dose to the hands or whole body. Unless there are compelling reasons not to, wipe down the enclosure if the buildup is contributing more than 10% of the worker's dose.
  - Use radiation shielding where appropriate. For example, installation of leaded Plexiglas overlays on enclosures with high levels of low-energy photon emitters (e.g., Am-241) can significantly reduce the external dose rate to workers.
  - Store radioactive materials in glove boxes, source pits, water pools, or other devices according to the degree of hazard and the nature of the material.

    Note: Use extra care when assessing potential hand dose, as the dose rate on the outside of a shielded enclosure may be insignificant, but the dose rate through the enclosure gloves may be quite high.

- Prevent glove damage.
  - Routinely survey enclosure gloves. If there is any breach of the gloves, or if radiation levels are significantly elevated, call the ES&H Team health and safety technician to change the glove.
  - Cover glove ports with a hard barrier if gloves will not be used during the shift.
  - Tie gloves outside the box when not in use.
- Exercise sound contamination control techniques.
  - Periodically survey for contamination around the glovebox access ports, connecting flanges, and other items in the work area. If contamination is found on the external surfaces of the glovebox, call the ES&H Team health and safety technician.
  - When accessing contaminated lines or enclosures, use drapes under the area of the planned break to minimize the spread of contamination.
- Maintain a safe workplace.
  - After flammable liquids are used, but before introducing potential ignition sources (e.g., hot plates) or using any electrically powered equipment, flush the enclosure's atmosphere until the concentration of any vapors is reduced to an acceptable level.
  - Exercise good housekeeping practices; do not permit waste to accumulate. The competing issues of good housekeeping and waste generation should be balanced sensibly.
- Limit routine access to the workplace to individuals who are needed to perform or support the operation or other operations in the workplace.

3.9 Moving Radioactive Materials

Radioactive material, including radioactively contaminated items, may be conditionally released for movement onsite only if the monitoring and controls specified in this section are followed. The program shall contact the ES&H Team before moving large, bulky, or unusual items (e.g., gloveboxes or milling machines). Violations of the requirements in this section shall be reported to the facility associate director's assurance manager, who will evaluate the situation and determine if a report shall be sent to DOE.

3.9.1 Moving Items with Fixed Contamination

Material and equipment with fixed contamination levels that exceed the total surface contamination values specified in Appendix D of this document may be moved from a Radiological Area for use in a controlled area if both of the following conditions are met:

- Removable surface contamination levels are below the values specified in Appendix D.
- The material or equipment is routinely monitored and clearly marked or labeled to alert personnel of the contaminated status.

3.9.2 Moving Radioactive Materials within a Facility

Radiological workers may move radioactive materials from one controlled area to another within the same building, or from a controlled area to the local Waste Accumulation Area (WAA), if all of the following conditions are met:

- The item is packaged, wrapped, or contained to prevent the spread of contamination.
- The external packaging does not have detectable contamination, as determined by a direct survey or a wipe evaluated with an appropriate hand-held radiation detector or on a Liquid Scintillation Counter.
- The item or package is properly labeled or remains in the custody of a trained radiation worker.
- The item is immediately placed in a controlled area.
- The Material Balance Area (MBA) representative is notified in advance of the movement of any controlled items (e.g., precious metals, Special Nuclear Materials).

3.9.3 Moving Radioactive Materials from a Facility

Radioactive material may be transferred from one onsite facility to another by a radiological worker *if* the total amount of activity is less than the Class III values listed in Appendix E *and* the controls listed in this section are followed. Only the Materials Management Section or Radioactive and Hazardous Waste Management (RHWM) Division personnel may transfer radioactive material that exceeds the Class III values in Appendix E. These organizations shall also transfer lesser amounts of material, as requested. Only RHWM personnel may transfer waste from a facility.

Packaging. General packaging requirements are specified in the *Onsite Hazardous Materials Packaging and Transportation Safety Manual* (UCRL-MA-108269). In addition, the following requirements apply:

- Radioactive material shall be packaged so that it does not present a hazard to individuals or the environment.

- Transuranic elements exceeding the Class III values in Appendix E of this document shall be packaged in sealed, double containers, one of which shall be metal.
- Highly dispersible radioactive material shall be packaged in a sealed, double container.
- Radioactive liquids not contained in carboys or retention tanks shall be packaged in leak-tight containers surrounded by an absorbent material sufficient to absorb all liquids in the container in the event of a spill. RHWM personnel shall transport carboys and retention tanks.
- Containers shall be fabricated from materials that can withstand the rigors of transportation, handling, and storage (e.g., contact with sharp edges, rough handling, or dropping). Consideration should be given to the length of time that the container will be in use and how the environment may affect its integrity. Information on radioactive materials packaging can be obtained from RHWM, the Materials Management Section, and the ES&H Team.
- Fissile materials shall be packaged in a manner that will prevent a criticality accident. See Document 20.6 or contact Hazards Control's Criticality Safety Group for assistance.

Monitoring. Hazards Control is responsible for conducting the monitoring described in this section, but it may be performed by:

- The Materials Management Section for offsite shipments and material being transferred from areas under its direct control (e.g., the Materials Management vaults).
- RHWM Division for waste being transported between its facilities (including WAAs).

If contamination is detected, the ES&H Team shall be contacted to evaluate the situation.

Prior to transferring radioactive material or contaminated items from a facility, monitoring of the package exterior is required, as described in Table 3.

Table 3. Monitoring requirements for transfer of radioactive material from a facility.

Type of material	Radiation survey[1] required?	Contamination survey[2] required?
Low-energy beta emitters (e.g., tritium, Carbon-14, and Nickel-63)	No	Yes Swipe-tab survey evaluated with an appropriate low-energy counter (e.g., a Liquid Scintillation Counter [LSC]).
Class I and II sealed radioactive sources	Only for offsite transfers	Only for offsite transfers (as specified for 'Other radioactive material').
Samples collected for radioactive analysis (e.g., swipes or air filters)	No	Only if the sample container is suspected of being externally contaminated.
Other radioactive material	Yes	Yes. Direct survey required. Swipe survey[3] also required if: • Areas of the package cannot be directly surveyed for contamination. • Contamination is detected during the direct survey. • The radiation emitted from the package interferes with the direct survey. • The package contains transuranics.

[1] Radiation surveys measure the dose rate on the outside of the package and are typically conducted with a micro-R meter, an ionization chamber, and/or a neutron meter.

[2] Contamination surveys measure fixed and removable contamination on the outside of the package. Direct surveys for fixed and removable contamination are typically conducted by directly surveying the package exterior with an alpha meter or an Eberline E-120 with a pancake probe. Surveys for removable contamination are conducted using a swipe tab or a large area wipe and evaluating the tab or wipe with an appropriate detector.

[3] For *offsite* transfers (e.g., those received from offsite or to be sent offsite), surveys for removable contamination shall be conducted by swiping the packages with a swipe tab. Swipe tabs may be evaluated on a field swipe counter (as specified in the LLNL *Swipe Manual)* or a field liquid scintillation counter (as appropriate), or submitted to a counting laboratory (e.g., Hazards Control's Radiation Measurements Laboratory). For *onsite* transfers, surveys for removable contamination may be conducted by wiping large areas with a kimwipe and evaluating the wipe with a hand-held radiation detector. If activity above background is detected, a swipe-tab swipe shall be taken and evaluated in the same manner as swipes taken for offsite shipments.

Monitoring results shall be documented on the Controlled Materials Identification (CMID) tag, the RHWM Waste Disposal requisition form, or the shipping papers. Packages shall not be transferred if contamination on the external packaging exceeds the levels specified in Appendix D of this document.

Resurveys. If the item is not removed from the area promptly after being monitored, it shall be protected from cross contamination (e.g., by covering it, wrapping it, or placing it in an area known to be free of contamination) or resurveyed prior to release. The

package shall also be resurveyed if it is opened, altered, damaged, or not removed from the area within 15 calendar days of the initial survey. Waste containers and items packaged in accordance with DOT requirements that are not shipped offsite within 15 days may be resurveyed using the large-area swipe technique for onsite shipments. If the containers are not shipped offsite within 90 days, they shall be resurveyed using the swipe-tab method required for offsite shipments.

Receipt surveys. Monitoring of the package exterior shall be conducted upon arrival in the new location if the package shows evidence of degradation, such as being crushed, wet, or damaged.

The individual opening the package shall monitor the interior package, even if there is no evidence of package degradation. If unexpected levels of contamination are found, the ES&H Team health and safety technician shall be notified to evaluate the situation. The procedure for opening and surveying packages is as follows:

1) Put on disposable gloves and move the item to where it is to be opened.
    - If the source is in a loose and dispersible form (e.g., a powder or liquid), open the package in a chemical fume hood, if feasible. If the package is too large to place in a hood, place the package in front of the hood.
    - If the material is non-dispersible (e.g., activated metal and sealed sources), the package may be opened on a benchtop.
2) Examine the label on the primary vial or container to confirm that the radionuclide and activity agrees with the information on the packing slip or CMID tag. If not, notify the Procurement and Materiel Department (if the material has just been received from the vendor) or the Materials Management Section.
3) Use a swipe tab to swipe the outside of the primary container (e.g., the vial containing the radioactive material) and assess the swipe with a liquid scintillation counter or a hand-held contamination monitor such as an Eberline E-120 with an HP-210 (i.e., "pancake") probe, as appropriate. (If you are unsure of how to survey for the given type of radiation, contact your E&SH Team health and safety technician.) Remove your gloves.
4) If contamination on the outside of the primary container is **less than 10 times the background level**, proceed with use of the material.
5) If contamination on the outside of the primary container is **equal to or greater than 10 times background**, contact the ES&H Team health and safety technician. The following are some options for handling the contaminated container; the ES&H Team health physicist may provide additional options.
    - Reject the shipment (i.e., repackage it in a clean container and return it to the vendor) and notify the Procurement and Materiel Department.

- Decontaminate the item to an acceptably low level and proceed with its use. In addition, determine whether the package that contained the primary vial is contaminated. If so, the packaging material shall be disposed of as radioactive waste.
- Dispose of the primary container and its contents as radioactive waste. Notify the Procurement and Materiel Department of the situation.
- With the assistance of the health and safety technician, transfer the material to another container.

Note: Upon request, the ES&H Team health and safety technician will assist with the opening of packages.

Transport controls. Only the Materials Management Section, or those authorized by the Materials Management Section, may ship or transport radioactive material (other than waste) offsite (including to and from Site 300). DOT forms shall be used when shipping material offsite. Only RHWM Division employees may transport waste offsite.

The *Onsite Hazardous Materials Packaging and Transportation Safety Manual (HMPTS Manual)* (UCRL-MA-108269) establishes LLNL's policy for the onsite transport of hazardous materials, substances, and wastes within the geographically contiguous property of LLNL and to Site 300.

The individuals identified in Table 4 may transport radioactive material onsite. The individual or organization that wants the radioactive material moved is responsible for making the following transfer arrangements:

- For all radioactive material other than waste, contact the ES&H Team health and safety technician to monitor the package and to ensure the packaging and labeling is adequate.
- If the radioactive material is waste, contact the RHWM technician to ensure the waste is properly characterized, labeled, and transferred.
- If the radioactive material exceeds the respective Class III value in Appendix E, contact the Materials Management Section to transport the material between facilities.

Except for Class I and II sealed sources and samples collected for analysis, a CMID tag or a waste disposal requisition shall be used to transfer radioactive material onsite. A copy of the CMID tag shall be retained by each of the following individuals:

- The ES&H Team health and safety technician in the originating facility.
- The person or organization making the transfer (i.e., the radiological worker or the Materials Management Section).

Table 4. Individuals authorized to transport radioactive material onsite.

Type of material	Authorized individuals
Radioactive material up to the respective Class III values in Appendix E	A radiological worker or A Hazards Control health and safety technician or health physicist or The Materials Management Section
NRC-exempt or generally licensed articles and items	The owner, user, or any other individual that abides by the NRC license requirements
Samples collected for radioactive analysis	Sample collector or others who are appropriately trained
Waste	Radioactive and Hazardous Waste Management
Radioactive material meeting or exceeding the respective Class III values in Appendix E Materials and equipment exceeding the removable surface contamination values specified in Appendix D of this document	The Materials Management Section or Others authorized by the Materials Management Section to hand-carry items. (Monitoring and packaging requirements still apply.)

- The ES&H Team health and safety technician in the receiving facility. The person or organization transporting the material is responsible for providing the ES&H Team health and safety technician with the CMID tag.

Radioactive material that is transported on-site may NOT be transported on bicycles or in privately owned vehicles, and if transported in a car, shall be located in the trunk (whenever feasible).

3.10 Sealed Radioactive Sources

Sealed radioactive sources are categorized as Class I, II, III, or IV. The specific values for Class III and IV sources are presented in Appendix E of this document.

- Class I sources contain >1 nCi of activity but are not Class II, III, or IV.
- Class II sources are
  - Sealed sources that have been acquired under an NRC general license and require periodic leak testing.
  - Sealed sources that the source custodian wants to administratively control (e.g., National Institute for Standards and Technology [NIST] traceable calibration standards) but are not Class III or IV sources.

- Class III sources contain at least the amount of activity specified in 10 CFR 835, Appendix E, but are not Class IV sources.
- Class IV sources contain 50 times the 10 CFR 835 Appendix E values.

Source custodians should maintain a list of Class I sources assigned to them, and should inform the Materials Management Section upon administrative transfer of the source to another source custodian. The Materials Management Section will include in the database sealed sources that have 1 μCi or more of radioactivity and shall maintain a list of all Class II, III, and IV sealed sources.

Class II, III, and IV sealed radioactive sources shall be inventoried at intervals not to exceed six months. This inventory shall:

- Establish the physical location of each accountable sealed radioactive source.
- Verify the presence and adequacy of associated postings and labels.
- Establish the adequacy of storage locations, containers, and devices.

Except for sealed radioactive sources consisting solely of gaseous radioactive material or tritium, each accountable sealed radioactive source shall be subject to a leak test upon initial receipt at LLNL, when damage is suspected, and at intervals not to exceed six months.

Accountable sealed radioactive sources are not subject to source leak testing if removed from service, but they shall be leak tested before being returned to service. These sources shall be stored in a controlled location and shall still be inventoried on a semiannual basis. In general, sources that are stored in the Materials Management vaults or in shipping containers are considered to be "removed from service." Other sources that may be unused but are still available in the work area shall be inventoried and leak tested. However, an accountable sealed radioactive source is not subject to periodic inventory and source leak testing if it is located in an area that is unsafe for human entry or is otherwise inaccessible.

The source custodian is responsible for making the source available to the ES&H Team health and safety technician for inventory and leak testing. Records shall be maintained to demonstrate that Class III and IV sealed sources are controlled, inventoried, and leak tested.

3.11 Spill Response

A spill is an unplanned release of radioactive material that can result in an intake of radioactive material, contamination of the skin or personal clothing, or contamination

outside a Type 0, I, II, or III workplace. If a spill of radioactive material occurs and workers are seriously injured, call 911. Otherwise, the individuals present should:

- Reach a safe stopping point for work in progress.
- Take reasonable steps to keep the situation from becoming worse but only if it is safe to do so.
- Move seriously injured persons only if necessary to prevent significant additional exposure. Care of serious or life-threatening injuries always takes precedence over contamination control measures.
- Leave the area of contamination and close the doors.
- Prevent others from entering the contaminated area.
- Call the ES&H Team.
- Notify the authorizing individual or facility management of the event.

Workers shall immediately notify the work supervisor and the ES&H Team of suspected intakes of radioactive material. Elevated air-sampling or air-monitoring results, facial contamination, or significant body contamination may be indicative of an intake of radioactive material. Where a high dose is possible, prompt medical attention can significantly reduce the radiation dose. For some radionuclides (e.g., transuranics), prompt bioassay will allow for the detection of doses below 0.1 rem.

Bioassay may include:

- Nasal wipes (which need to be taken within 45 minutes of intake).
- Wound, lung, or whole body counting (usually conducted on the day of the incident).
- Fecal analysis or urinalysis (conducted a day or more after the incident).

Workers with a verified intake shall participate in a follow-up bioassay program sufficient to determine the magnitude of the intake and the resultant dose. The Internal Dosimetry Program coordinator shall determine the bioassay protocol.

Hazards Control or Health Services shall direct personnel decontamination efforts, which may include washing with soap and water, scrubbing with a soft bristle brush, applying external chemical decontaminants, administering internal chemical decontaminants (e.g., chelation therapy), or excising tissue around a wound. These procedures are described in Appendix C. Field decontamination by untrained individuals can result in significantly higher doses to the individual and therefore should NOT be undertaken unless the contaminant is associated with a strong acid or base and skin damage will occur without prompt flushing of the affected area.

Restoring the contaminated area to normal is the responsibility of the programmatic organization. Hazards Control and the Environmental Protection Department will provide guidance and assistance.

3.12 Area Monitoring

Area monitoring shall be performed to:

- Demonstrate compliance with the Rule.
- Document radiological conditions.
- Detect changes in radiological conditions.
- Detect the gradual buildup of radioactive material.
- Verify the effectiveness of engineered and process controls for containing radioactive materials and reducing radiation exposure.
- Identify and control potential sources of individual exposure to radiation and radioactive materials.

The ES&H Team is responsible for conducting and documenting area monitoring. Others may assume this responsibility only if facility and program management, the ES&H Team leader, and the RPP-SME agree to it in writing. Individuals conducting the monitoring shall be specifically identified and trained, and shall maintain monitoring records in the same manner as those generated by the ES&H Team.

Changes in equipment, techniques, and procedures used for monitoring the workplace shall be documented.

3.12.1 Contamination and Radiation Monitoring

The ES&H Team health physicist shall prescribe, and the health and safety technician shall conduct, routine radiation and contamination monitoring to meet the requirements in Section 3.12. The frequency of routine monitoring shall be based on the type and amount of material to be handled and the type of work involved (e.g., machining, wet chemistry, or dry chemistry). Table 5 gives the minimum frequency for conducting routine radiation surveys.

The routine monitoring conducted by the ES&H Team is not designed to detect day-to-day changes that result from ongoing operations. Therefore, radiological workers (i.e., programmatic personnel) are responsible for conducting operational surveys during work and other programmatically driven surveys and for notifying the ES&H Team of changes in workplace conditions or of unplanned events.

Table 5. Minimum frequency of routine radiological surveys conducted by the ES&H Team.[a,b]

Area Posting	Area Contents	Contamination surveys		Radiation surveys[c]	
		Active[d]	Inactive[e]	Active[d]	Inactive[e]
RMA	Type 0 workplace (WP)	S	S	S	S
RMA	Type 1 WP, or Type 2 or 3 WP with Type 1 quantities of material	Q	S	Q	S
RMA	Type 2 or 3 WP	M	Q	M	S
RMA	Items with external removable contamination	M	Q		
Contamination area		M	Q[f]		
High contamination area		W	M[f]		
Radiation area				M[g]	Q
High radiation area				W	Q[f]

a S = Semiannual; Q = Quarterly; M = Monthly; W = Weekly.

b These surveys are intended to detect changes in the workplace. More frequent surveys may be appropriate depending on operational issues and are specified by the ES&H Team health physicist, as appropriate.

c Radiation surveys are required only if external radiation fields are of sufficient energy and intensity to be detected.

d "Active" means that radioactive material is routinely handled or moved.

e "Inactive" means that radioactive material is not routinely handled or moved.

f At a minimum, survey the area boundary.

g More frequent (e.g., weekly) surveys are appropriate in areas where significant fluctuations in dose are likely.

3.12.2 Air Sampling and Monitoring

The derived air concentration (DAC) values given in Appendices A and C of the Rule shall be used in the control of occupational exposures to airborne radioactive material. Sampling of airborne radioactivity shall be performed:

- Where an individual is likely to receive an exposure of 40 or more DAC–hours in a year (an intake equivalent to 0.1 rem/y).
- As necessary to characterize the airborne radioactivity hazard where respirators have been prescribed for protection against airborne radionuclides.

Real-time air monitoring with a continuous air monitor (CAM) shall be performed to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material. Each CAM shall have a logbook that documents the CAM alarm set point, air flow rate, function checks, and date of filter changes. It is preferable to also include the time of the filter change.

If a CAM alarms, workers who are not wearing a respirator shall immediately leave the room. Individuals wearing a respirator should reach a safe stopping point for work in progress and then leave the room, unless otherwise specified in a safety plan. Anyone in the area at the time a CAM alarms shall remain in the building (near where the CAM alarmed) until the ES&H Team responds and conducts a survey.

Air flow studies should be used to determine the placement of air samplers/monitors. In general, samplers/monitors are appropriately placed in any of the following locations:

- Near the potential release point(s).
- At exhaust locations.
- In the individual's work location.

Placement of fixed-location samplers/monitors should be reevaluated after changes to the ventilation system have been made, or after equipment or structures have been added that may influence air flow. Air flow patterns in a given area should be reevaluated at least every 36 months.

The ES&H Team is responsible for determining the appropriate number and locations for air sampling and monitoring, and for exchanging and submitting filters for analysis. Program personnel may not change, modify, turn on or off, or move air samplers or monitors without the explicit concurrence of the ES&H Team. The ES&H Team health physicist shall document the air monitoring program in a given facility using the Air Sampling and Monitoring Form contained in the HP-DAP. Alternate formats (e.g., a formal report) that include the information in the Air Sampling and Monitoring Form are also acceptable.

New or modified operations that have the potential to release radioactive material to the ambient air during normal operations shall be reviewed by the Terrestrial and Atmospheric Monitoring and Modeling (TAMM) Group of the Operations and Regulatory Affairs Division in the Environmental Protection Department (EPD). Use of emission control devices, such as HEPA filtration, can obviate the requirement for startup approval from the Environmental Protection Agency (EPA).

Startup approval is required if the effective dose equivalent (EDE) to any member of the public is 0.1 mrem/y or greater. In addition, continuous sampling of the air effluent is required if the EDE (without allowance for control devices) exceeds 0.1 mrem/y. More detailed information can be found in Document 31.1, "Air Quality Compliance," in the *ES&H Manual*.

3.13 Personnel Monitoring

Changes in equipment, techniques, and procedures used for monitoring individuals shall be documented. The organization that is responsible for the change is responsible for the documentation. For example, facilities are responsible for documenting changes in the location or type of installed equipment such as radiation area monitors or continuous air monitors. Hazards Control is responsible for documenting institutional changes such as the personnel dosimetry or bioassay monitoring systems.

3.13.1 Contamination Monitoring

Depending on the type of work conducted, personnel surveys may or may not be required upon leaving an RMA. For example, hand and shoe surveys are generally not required where nondispersible or low levels of dispersible radioactive materials are handled (such as in Type 0 and I workplaces). However, surveys are generally required if

- Operations require higher levels of PPE (e.g., coveralls).
- Operations produce dispersible radioactive material (e.g., a uranium machine shop).
- The RMA contains a Type III workplace.
- Past experience indicates a potential for cross-contamination.

The ES&H Team health physicist shall determine the monitoring requirements and individuals shall comply with them.

If a hand and shoe monitor alarms during a survey, or if activity is detected on a hand-held detector, the worker shall

- Conduct two more surveys. If the detector does not alarm or contamination is not detected on the subsequent surveys, the worker may leave the area. If the detector alarms or contamination is detected on either of the follow-up surveys, the worker shall call the ES&H Team and wait in the immediate area until assistance arrives.
- Prevent others from walking through potentially contaminated areas until the ES&H Team arrives and takes control of the area.

Individuals exiting Contamination, High Contamination, or Airborne Radioactivity Areas shall be monitored, as appropriate, for the presence of surface contamination.

3.13.2 External Dose Monitoring

External dose monitoring requirements are specified in Document 20.1.

3.13.3 Internal Dose Monitoring

The internal dose monitoring program typically involves bioassay monitoring but may also involve air sampling and contamination monitoring. Routine bioassay monitoring consists of a combination of urinalysis, whole-body scans, or lung counts. The following individuals shall participate in a routine bioassay program:

- Workers who, under typical conditions, are likely to receive a committed effective dose equivalent (CEDE) of 0.1 rem or more from all occupational radionuclide intakes in a year.
- Occupationally exposed minors and members of the public who are likely to receive an internal dose exceeding 0.05 rem (CEDE) in a year.
- Declared pregnant workers who are likely to receive an internal dose equivalent to the embryo/fetus exceeding 0.05 rem (CEDE).
- Other individuals who are likely to receive significant intakes of radioactive materials under typical or off-normal conditions. (Guidelines for determining participation in internal dose monitoring programs are contained in the *LLNL Internal Dosimetry Program Manual*.) This best management practice ensures low-level internal doses are detected and provides verification that engineered controls and workplace practices are effective.

Bioassay programs typically include prestart (i.e., baseline), periodic, and termination monitoring. The ES&H Team health physicist, in conjunction with program personnel and the Internal Dosimetry Program coordinator, is responsible for identifying workers who require bioassay monitoring, the type of bioassay needed, and the appropriate frequency.

Employees enrolled in a bioassay program should inform the ES&H Team health physicist of any medical treatments involving radionuclides, because these materials may interfere with some bioassay techniques or mask the presence of the radionuclide(s) of interest. Program management is responsible for notifying the ES&H Team health physicist of changes in workers or operations that may affect the bioassay program, and for ensuring that workers are enrolled and participate in the prescribed bioassay program. The *LLNL Internal Dosimetry Program Manual*, maintained by Hazards Control, contains more information on monitoring requirements, selection of employees, selection of appropriate bioassay methods and frequencies, bioassay and dose data management, dose assessment procedures, and dose management policies.

3.13.4 Pregnant Workers

The radiation dose limit to the embryo/fetus of a declared pregnant worker is 0.5 rem. Declared pregnant workers shall be included in the bioassay program if the

embryo/fetus is likely to receive 0.05 rem from internal sources. Information on LLNL's declared pregnant worker policy can be found in Document 20.1.

3.14 Eating and Drinking

Eating, preparing or storing food, and drinking are not permitted in RMAs with Type I, II, or III workplaces. In areas where offices and laboratory spaces are intermingled, "clean spaces" may be established for eating and drinking if approved by facility management with the concurrence of the ES&H Team health physicist.

Drinking from water fountains in RMAs is allowed unless otherwise restricted by the ES&H Team. The ES&H Team health physicist shall concur with the installation of water fountains in an RMA.

3.15 Disposing of Radioactive Material

3.15.1 Contaminated Items

Articles and equipment that are contaminated with radioactive material and are no longer needed for LLNL operations may be treated as follows:

- Decontaminated and free released for reuse or recycling (assuming they meet the release criteria).
- Left contaminated and used in a controlled manner.
- Disposed of as radioactive waste.

The E&SH Team, RHWM Division, and the programmatic organization jointly determine the feasibility of decontaminating articles and equipment. RHWM Division may assist in the decontamination effort, but the program is responsible for the cost of the decontamination. The ES&H Team shall determine if the decontamination efforts are sufficient to allow free release of the item. Document 21.5, "Requirements for Transfer of Equipment and Property for Repair, Reuse, Maintenance, Storage, Excess or Scrap," in the *ES&H Manual* contains detailed information.

3.15.2 Waste

Waste from an RMA shall be segregated based on its potential for contamination, fire, the level of contamination, the type of contamination (e.g., radioactive, hazardous, or transuranic), whether the material is liquid (aqueous or organic) or solid, and whether the waste is compactible or not. The waste generator shall control the waste until it is transferred to RHWM . If the waste generator cannot certify that the waste is free of radioactive contamination, it shall be sampled and analyzed. Contact the RHWM technician for assistance.

Radioactive waste (liquid or solid) shall not enter domestic waste-disposal channels (e.g., the sanitary sewer or the municipal trash). Radioactive waste should not be diluted with waste that is known to be nonradioactive. Although some workplaces have sinks connected to retention-tank systems, radioactive wastes should still be disposed of in the local containers provided. Retention-tank systems are not installed for the purpose of collecting radioactive waste but rather to ensure that any effluent leaving the workplace is checked for radioactivity and other contaminants before it is properly disposed of in the sanitary sewer. Release of the contents of a retention tank to the sanitary sewer requires evaluation by and permission from the Environmental Protection Department.

Radioactive waste receptacles shall be conspicuously labeled as containing radioactive waste. Container lids should be kept in place except when the receptacle needs to be open. Reusable radioactive waste cans (e.g., those typically found in a laboratory) should be painted yellow to ensure they are visually distinctive from other types of waste. When more than one type of waste is generated in an area (e.g., municipal trash, hazardous waste, and nonhazardous [industrial] waste), waste cans for the different types of waste should be uniquely labeled and separated to the extent practicable. The custodial staff is not permitted to empty radioactive waste containers unless they are specifically trained and authorized to do so.

There are specific release criteria for volumetrically contaminated waste. Guidance is provided in *Waste Acceptance Criteria* (UCRL-MA-115877). Programmatic organizations should contact the ES&H Team environmental analyst for detailed information on solid and liquid radioactive waste-handling requirements.

3.16 HEPA-filtered Vacuums

HEPA-filtered vacuum cleaners shall be appropriate for the type and amount of radioactive material involved. The ES&H Team health physicist is responsible for determining the levels of filtration required on the vacuum exhaust. Programmatic organizations are responsible for the following:

- Maintaining control of HEPA-filtered vacuums.
- Ensuring that the Hazards Control Industrial Hygiene Laboratory tests HEPA-filtered vacuums annually. Vacuums shall be retested if the integrity of the filter media or the sealing surface of the HEPA filter is compromised, or if the HEPA filter is exposed to water or high levels of water vapor.
- Ensuring that HEPA-filtered vacuums are properly labeled, controlled to avoid improper use, serviced or emptied only by individuals trained to do so, and that the ES&H Team health physicist is contacted before they are opened.

3.17 Training

Document 20.1 contains the following:

- Institutional training requirements for access to radiologically controlled areas (i.e., areas posted with the radiation trefoil symbol) and for radiological work. The courses that apply to radioactive material handling are summarized in Table 6.
- Local training requirements that may be required for work in specific facilities or organizations.
- Retraining requirements and provisions for use of escorts in lieu of training.

Table 6. Radiation safety training courses pertaining to radioactive material handling.

Course	Applicability
HS6001, "General Employee Radiological Training" (GERT) Retraining is achieved every 24 months by the mailing of a booklet.	Required prior to receiving occupational dose in an area posted with the radiation symbol, and for • Unescorted access into a Radioactive Materials Area. • Escorted access into Radiation/High Radiation Areas, Contamination/High Contamination Areas, or Airborne Radioactivity Areas.
HS6901, "Radiological Worker Core Training" or equivalent	Required for • Unescorted access to Radiation Areas. • Any person likely to received >0.1 rem/y who is not a radioactive material handler or radiation generating device (RGD) operator.
HS6010, "Radiological Worker"*	Required for • Work with only nondispersible radioactive material. • Unescorted access into a High Radiation Area, or Very High Radiation Area.
An HS6300 series course: "Contamination Control" or one of the "Radioactive Material Handling" courses	Required for • Work with dispersible radioactive material. • Unescorted access into a Contamination/High Contamination Area or Airborne Radioactivity Area.
HS6340, "Anti-Cs"	Required for work where full anticontamination clothing is necessary (e.g., coveralls with the openings taped, shoe covers, gloves, and respirator).
HS6390, "Introduction to Glovebox Safety"	Required (one time only) for work conducted in gloveboxes.
HS6913, "Chelation Therapy"	Recommended for individuals conducting glovebox work with transuranic radioactive material. This course is available upon request by the programs. Retraining is not required.

* HS6300 is an alternate for HS6010

4.0 Design Criteria for Type I, II, and III Workplaces

This section contains minimum design criteria for Type I, II, and III workplaces. These criteria are established to control radioactive material and radioactive contamination. Exposure rate design criteria are contained in Document 20.4. The ES&H Team health physicist may specify additional criteria on a case-by-case basis, depending on the operations involved. For example, a tertiary barrier may be required for operations that could potentially breach the primary or secondary barrier. If the minimum criteria specified in this section are impractical or not cost-effective to implement, the ES&H Team health physicist may determine alternate means of achieving a commensurate level of safety.

Note: The Environmental Protection Department may have specific effluent monitoring requirements not directly associated with worker protection; therefore, programs shall involve their ES&H Team environmental analyst in the planning process for new operations with dispersible radioactive material.

4.1 General Design Criteria

Following are general design criteria for Type I, II, and II workplaces. Additional criteria for each type of workplace are listed below each heading in the following subsections.

- The design or modification of a facility and the selection of materials shall include features (e.g., smooth and impermeable floors and work surfaces) that facilitate operations, maintenance, decontamination, and decommissioning.
- The design objectives for controlling airborne radioactive material shall be, under normal conditions, to avoid releases to the workplace atmosphere and, in any situation, to control the inhalation of such material by workers to levels that are as low as reasonably achievable. Confinement and ventilation normally shall be used. Administrative controls and protective clothing shall be considered supplemental means to limit intakes.
- The workplace shall have adequate airflow, as determined by the ES&H Team health physicist and industrial hygienist. As specified in Document 12.2, "Ventilation," in the *ES&H Manual*, the typical ventilation rate for a laboratory is 4 to 12 air changes per hour. Appropriate ventilation rates for large areas, such as high bays, shall be determined on a case-by-case basis.
- Facility ventilation systems shall draw air from areas with a low potential for contamination to areas with a higher potential for contamination.
- Separate containers shall be provided for solid and liquid radioactive waste.

4.2 Type I Workplaces

The general design criteria in Section 4.1 satisfies the requirements for a Type I workplace. Use of a laboratory benchtop will typically suffice.

4.3 Type II Workplaces

The design criteria for Type II workplaces is as follows:

- One barrier shall be present between the worker's breathing zone and the radioactive material. If airflow is being used as a barrier (e.g., as provided by a chemical fume hood), annual testing of the ventilation system is required to ensure it is operating effectively.
- Hoods shall be designed to prevent turbulent flow.
- The design and use of enclosures shall conform with the criteria stated in Document 12.4, "Work Enclosures and Local Exhaust Systems for Toxic and Radioactive Materials," in the *ES&H Manual*.
- Equipment and engineered controls shall be tested and the results documented before radionuclides are introduced. The ES&H Team shall either conduct or concur with the testing. Testing includes, but is not limited to, ensuring that the ventilation system operates as specified, HEPA filters are properly installed and tested, and equipment to be used in the enclosure operates as designed.
- The need for installation of the following features shall be determined on a case-by-case basis:
  - A flow alarm that activates when the flow is outside the specified operational range.
  - A HEPA filter or scrubber on the enclosure.

Use of a chemical fume hood will typically satisfy all of the above criteria.

Use of ventilated enclosures (e.g., hoods or gloveboxes) with recirculating air systems (e.g., air systems that exhaust to the room air) is strongly discouraged. The ES&H Team health physicist shall concur with the use of such equipment.

4.4 Type III Workplaces

The design criteria for Type III workplaces is as follows:

- Two barriers shall be present between a person's breathing zone and the radioactive material. One barrier shall have structural integrity.

- Equipment and engineered controls shall be tested and the results documented before radionuclides are introduced. The ES&H Team shall either conduct or concur with the testing method and results. Testing includes, but is not limited to, ensuring that the ventilation system operates as specified, HEPA filters are properly installed and tested, and equipment to be used in the enclosure operates as designed.
- Work rooms shall be maintained at negative pressure relative to other parts of the building. The ES&H Team health physicist shall approve the air flow pattern and pressure gradient in the facility.
- HEPA filtration shall be provided and include the following features:
  - For permanent installations containing a Type III enclosure, at least one of the room and glovebox HEPA filters should be installed outside of the room containing the Type III enclosure to protect the HEPA filters from hazards within the room. A housekeeping filter should be installed inside the room, close to the source of the radioactive material, to minimize duct contamination.
  - A pressure differential gauge (e.g., a Magnehelic gauge) that measures pressure drop across the HEPA filter. An alarming gauge is desirable.
  - For high-volume, dusty operations, a prefilter that prevents loading of the HEPA filter.
  - Filters that isolate radionuclides from ventilation systems and programmatic source lines.
- Pressure regulation shall be provided and include the following features:
  - A vacuum sensor and control device (e.g., a Fisher-Porter valve) designed to maintain the enclosure atmosphere at negative pressure relative to the outside of the enclosure.
  - A vacuum controller that sounds an alarm when outside the specified operational range.
  - Gas-delivery volume and pressure control to prevent overpressurizing the enclosure.
- Contamination controls shall include the following features:
  - Air sampling and monitoring capability in the work area, as specified by the ES&H Team health physicist.
  - Isolation from work areas with low-hazard operations.
  - Provisions for safely introducing and removing material from the workplace.
- Provisions for air sampling or monitoring shall be provided, as appropriate.

- Other protective devices (e.g., shielding, remote handling devices, air locks, bag-out ports, and alarming area radiation monitors) shall be used according to the degree of hazard associated with the operation.

Use of a HEPA-filtered, negative-pressure glovebox within a HEPA-filtered, negative-pressure monitored work area will typically satisfy all of the above criteria.

5.0 Responsibilities

The responsibilities for each individual and organization are listed below each title. These responsibilities are specific to radioactive materials operations and are in addition to the responsibilities identified in Document 20.1.

5.1 Authorizing Individuals

Authorizing individuals shall:

- Provide suitable workplaces and the resources for safe radiological operations.
- Conduct a management prestart review (MPR) and authorize radiological activities before they start.
- Restore an area to normal following a spill or release of radioactive material.

5.2 Responsible Individuals

Responsible Individuals shall:

- Ensure individuals exiting follow the prescribed monitoring procedures.
- Contact the ES&H Team
  - Before establishing, moving, or decommissioning a Type 0, I, II, or III workplace.
  - When changes in operations or workers affect the bioassay program.
- Ensure operations are conducted in appropriate workplaces.
- Ensure the appropriate individuals are enrolled in the bioassay program and that they provide bioassay samples on the specified frequency.

- Take reasonable steps to prevent the unauthorized and unintended use of radioactive materials. This may include locking doors to unattended laboratories or locking refrigerators or cabinets containing radioactive materials.
- Identify a source custodian for each Class II, III, and IV sealed source under programmatic control and ensure the custodian carries out his/her responsibilities.
- Maintain control of HEPA-filtered vacuums.

5.3 Radiological Workers

Radiological workers shall:

- Conduct work safely. This includes
  - Preventing inadvertent breach of barriers.
  - Preventing injuries (e.g., pinches and puncture wounds).
  - Promptly detecting and minimizing the spread of contamination.
  - Keeping your radiation dose as low as reasonably achievable.
  - Following approved plans and procedures.
- Use the appropriate tools and protective equipment.
- Use good contamination control techniques during routine and off-normal activities.
- Properly control the release of items from RMAs and Type I, II, and III workplaces.
- Properly control the transfer of materials between buildings in accordance with LLNL and Materials Management policies and procedures.
- Participate in the prescribed bioassay program.
- Clean up spills. The ES&H Team will provide assistance and guidance. RHWM will provide assistance with large spills.

5.4 Sealed Source Custodians

Sealed source custodians shall:

- Properly store, use, and control sealed radioactive sources, including those installed in equipment.
- Maintain an inventory list of Class I sources.

- Make Class II, III, and IV sealed sources available to the ES&H Team health and safety technician semiannually for inventory and leak testing.
- Notify the Materials Management Section of changes in source custodians and of the source locations.
- Promptly notify the Responsible Individual and the ES&H Team health and safety technician of any damaged sources or sources that cannot be located.

5.5 Materials Management Section

The Materials Management Section shall:

- Upon receipt of radioactive material at the vault, perform receipt surveys, ensure the material is properly labeled, and then deliver it to the ES&H Team health and safety technician in the facility where it is to be used.
- Transfer radioactive material and contaminated items between buildings. (Although Materials Management may transfer any amount of radioactivity, they are required to transport the item if the amount exceeds the Class III values listed in Appendix E.)
- Inventory sealed sources stored in the Materials Management vaults.
- Coordinate semiannual sealed-source inventories and leak tests with Hazards Control.
- Maintain the sealed source accountability database.

5.6 ES&H Team

This section specifies the responsibilities of the ES&H Team.

5.6.1 ES&H Team Health and Safety Technician

The ES&H Team health and safety technician shall fulfill the posting and monitoring requirements of the Rule. This includes:

- Performing the routine area monitoring specified by the ES&H Team health physicist.
- Conducting semiannual sealed source inventory and leak tests.
- Performing release surveys.
- Ensuring the suitability of workplaces and storage facilities.

5.6.2 ES&H Team Health Physicist

The ES&H Team health physicist shall:

- Establish a routine radiation- and contamination-monitoring program that meets the requirements in Section 3.12.
- Provide technical support to programs, consistent with the ALARA process. This includes
  - Determining the appropriate type of workplace (0, I, II, or III) and controls for an operation.
  - Determining if radioactive materials should be treated as dispersible or nondispersible and the number of barriers required for an operation.
  - Evaluating ventilated enclosures (e.g., hoods and gloveboxes) to determine their effectiveness as barriers.
  - Determining the appropriate location for air sampling and monitoring.
  - Specifying routine and supplemental dosimetry requirements.
  - Identifying individuals that are required to participate in a bioassay program as a result of the Rule or LLNL best management practice.
  - Increasing or decreasing the PPE requirements as area conditions change.

    Note: The individuals who authorized the safety plan shall concur with changes to PPE requirements specified in IWS/SPs and FSPs.
  - Approving installation of water fountains in RMAs.
- Inform the RPP-SME of changes to the RMMA list.

5.6.3 ES&H Team Environmental Analyst

The ES&H Team environment analyst shall:

- Review operations that have the potential to release radioactive material to the ambient air. Establish airborne effluent monitoring requirements.
- Determine the need for startup approval by the EPA or other regulatory agencies.

5.7 Radiation Safety Section

This section specifies the responsibilities of the Hazards Control Department Radiation Safety Section.

5.7.1 Radiation Protection Program Subject-Matter Expert

The RPP-SME shall:

- Authorize individuals who are not part of the ES&H Team to conduct and document surveys required by 10 CFR 835.
- Maintain the RMMA list based on input received from the ES&H Team health physicists.
- Ensure LLNL has a comprehensive sealed source control program.

5.7.2 Internal Dosimetry Program Subject-Matter Expert

The Internal Dosimetry Program SME shall:

- Recommend to the ES&H Team health physicist the appropriate bioassay program for workers performing routine operations and those suspected of receiving an intake of radioactive material.
- Evaluate intakes and calculate internal doses. The estimation of internal dose shall be based on bioassay data rather than on air concentration values unless bioassay data are unavailable or inadequate, or internal dose estimates based on air concentration values are demonstrated to be as or more accurate.
- Provide termination dose evaluations for individuals with internal doses.

5.8 Radioactive and Hazardous Waste Management Division

The RHWM Division (of EPD) shall:

- Provide waste-handling assistance to the programs.
- Transport waste between facilities and offsite.
- Provide assistance with large spills.

6.0 Work Smart Standards

10 CFR 835, "Occupational Radiation Protection." (Issued November 4, 1998, effective December 4, 1998).

7.0 Resources for More Information

7.1 Contacts

For additional information about working safely with radioactive material, workers should contact the following:

- Responsible Individual
- Authorizing individual (facility/program manager)
- Materials Management
- RHWM Division
- ES&H Team health and safety technician
- ES&H Team health physicist
- ES&H Team environmental analyst
- ES&H Team leader
- Hazards Control RPP-SME
- Hazards Control RSPL

Hazards Control personnel can be reached through the ES&H Contact.

7.2 Applicable Lessons Learned

The "Radiation Protection" category of the Lessons Learned Program contains information pertinent to radioactive material operations. The Lessons Learned Program is available on the Internet at the following URL address:

http://www-r.llnl.gov/es_and_h/lessons/lessons.shtml

7.3 Other Sources

For additional information about topics discussed in this document, refer to the following documents:

- *ES&H Manual,* M-010, Lawrence Livermore National Laboratory, Livermore, CA. The official version is available on the Internet at

  http://www.llnl.gov/es_and_h/esh-manual.html

- *Waste Acceptance Criteria,* Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MA-115877.
- *Criteria and Procedures for the Certification of Nonradioactive Hazardous Waste*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-AR-109988.
- *Onsite Hazardous Materials Packaging and Transportation Safety Manual*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MA-109662.
- 10 CFR 30.71, "Energy."

The following documents are located in Hazards Control and are maintained by the Radiation Safety Section. They shall be used by the ES&H Team in carrying out the requirements of this document:

- *Radiation Safety Sign Manual.*
- *Swipe Manual.*
- LLNL Internal Dosimetry Program Manual.

Guidance from the following documents has been incorporated into this document wherever feasible:

DOE G 441.1–12, "Radiation Safety Training Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/J1–Rev 1).

DOE G 441.1–4, "External Dosimetry Program Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/C2–Rev 1).

DOE G 441.1–3, "Internal Dosimetry Program Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/C1–Rev 1).

DOE G 441.1–8, "Air Monitoring Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/E2–Rev 1).

DOE G 441.1–13, "Sealed Radioactive Source Accountability and Control Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/M1–Rev 1).

DOE G 441.1–10, "Posting and Labeling for Radiological Control Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/G1–Rev 1).

DOE G 441.1–11, "Occupational Radiation Protection Record-Keeping & Reporting Guide," *10 CFR 835 Implementation Guide* (Formerly G–10 CFR 835/ H1–Rev 1).

DOE G 441.1–9, "Radioactive Contamination Control Guide, *10 CFR 835 Implementation Guide*."

Appendix A

Acronyms, Terms, and Definitions

The terms and definitions in this appendix are specific to their use in this document.

Accountable sealed radioactive source	A sealed radioactive source having a half-life equal to or greater than 30 days and an isotopic activity equal to or greater than the corresponding value provided for Class III sources in Appendix E of this document. See the definition of "sealed radioactive source."
Airborne radioactive material or airborne radioactivity	Radioactive material dispersed in air in the form of dusts, fumes, particulates, mists, vapors, or gases.
Airborne radioactivity area	Any area, accessible to individuals, where the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in 10 CFR 835, Appendix A or C, or where an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.
ALARA	See "As low as reasonably achievable."
ALI	See "Annual limit on intake."
Annual limit on intake (ALI)	The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man (International Commission on Radiological Protection [ICRP] Publication 23) that would result in a committed effective dose equivalent of 5 rem or a committed dose equivalent of 50 rem to any individual organ or tissue.
As low as reasonably achievable (ALARA)	An approach to radiation protection to manage and control individual and collective dose to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process, which has the objective of attaining doses as far below the applicable limits as is reasonably achievable.

Barrier	A physical means of containing radioactive material and protecting against internal radiation exposure. A barrier can be any of the following: • A proper negative airflow pattern, such as that provided by a chemical fume hood or a glovebox. • An enclosure, such as a glovebox. • A HEPA filter. • A sealed metal can. The seal may be a crimp seal, a welded seal, or a pressure-fit seal (e.g., as provided by a screw-top can). • A sealed plastic jar. Plastic jars may be sealed with a screw-top lid. • A sealed plastic bag. Bags may be heat-sealed or sealed with tape. A plastic bag is considered to have very limited structural integrity. • A cardboard carton (e.g., an ice cream carton) with a taped lid. A cardboard carton is considered to have very limited structural integrity. • Process vessels or equipment (e.g., piping or tanks).
Bioassay	The determination of kinds, quantities, or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from the human body.
CEDE	See "Committed effective dose equivalent."
Chemical fume hood	See "ventilated enclosure."
Committed effective dose equivalent (CEDE)	The sum of the committed dose equivalent to various tissues in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (w_T)—that is, $H_{E,50} = \Sigma w_T H_{T,50}$. Committed effective dose equivalent is expressed in units of rem.

Contaminated items or areas	Items or areas with internal or external surface contamination levels above the values specified in Appendix D of this document. If the level of contamination is more than 100 times the levels listed in this appendix, the item or area is highly contaminated. The ES&H Team health physicist shall individually evaluate volumetrically contaminated items.
Contamination Area	Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed (but do not exceed 100 times) the removable surface contamination values specified in Appendix D of this document.
Controlled area	Any area to which access is managed to protect individuals from exposure to radiation or radioactive material. At LLNL, controlled areas are posted with the radiation trefoil symbol.
Debridement	The removal of dead, damaged, or infected tissue from a wound in order to expose healthy tissue and allow the wound to heal.
Deep dose equivalent	The dose equivalent from external radiation at a depth of 1 cm in tissue.
Derived air concentration (DAC)	The airborne concentration that equals the ALI divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m^3).
Derived air concentration-hour (DAC-hour)	The product of the concentration of radioactive material in air (expressed as a fraction or multiple of the DAC for each radionuclide) and the time of exposure to that radionuclide, in hours.
Dispersible radioactive material	Radioactive liquids, powders, fines, solids with oxidized surfaces, and other forms that can be easily transferred to another surface or medium.
Dose	A general term for absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent.
Dose equivalent (H)	The product of absorbed dose (D) in rad (or gray) in tissue, a quality factor (Q), and other modifying factors (N). Dose equivalent is expressed in units of rem (or millirem [mrem]) (1 rem = 1,000 mrem).

Effective dose equivalent (H_E)	The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factor (w_T)—that is, $H_E = \Sigma w_T H_T$. It includes the dose from radiation sources internal and external to the body. For purposes of compliance, deep dose equivalent to the whole body may be used as the effective dose equivalent for external exposures. The effective dose equivalent is expressed in units of rem.
Entrance or access point	Any location through which an individual could gain access to an area controlled for the purpose of radiation protection. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.
External dose or exposure	The dose equivalent received from radiation sources outside the body (i.e., external sources).
Extremity	Hands and arms below the elbow or feet and legs below the knee.
Free release	Release of an item for unrestricted use.
GERT	General Employee Radiological Training.
Glovebox	An enclosure with glove ports that provides a complete physical barrier between the worker and the material. A glovebox is typically a metal enclosure with glove ports and plastic viewing windows. Shoulder-length gloves are attached to the glove ports to allow manipulation of material and equipment. The effluent from the box is filtered through a HEPA filter. The glovebox shall be maintained at negative pressure to the room; acceptable operating specifications shall be approved by the ES&H Team. Gloveboxes may contain an "inert" or air atmosphere. Transfer of material into and out of inert atmosphere gloveboxes is usually accomplished through an airlock or a bag-in/bag-out operation. Transfer of material into and out of air atmosphere gloveboxes is usually accomplished by opening a port on the side of the box (i.e., an open-air transfer). Additional information is provided in Document 12.4.

Note: Some gloveboxes are used to protect the product—as opposed to the worker—from contamination. The controls in this document do not apply to gloveboxes used for product protection.

HEPA filter	High-efficiency particulate air filters. A filter certified with a minimum particle removal efficiency of 99.97 percent for thermally generated, nondispere dioctyl phthalate (DOP) particles with a diameter of 0.3 μm. HEPA filters are described in Document 12.5, "High-Efficiency Particulate Air (HEPA) Filter System Design Guidelines for LLNL Applications," in the *ES&H Manual*. HEPA filters required for the control of toxic or radioactive materials shall be leak tested in place before use and at least annually thereafter. Filters that are not tested annually, but are used as a best management practice to reduce contamination are referred to as "housekeeping HEPA filters." Housekeeping filters installed on gloveboxes may contain extremely high levels of radioactivity. Filter efficiency and testing requirements may be different for clean-room applications.
High Contamination Area	Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Appendix D of this document.
High Radiation Area	Any area, accessible to individuals, where radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem in one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
Internal dose or exposure	The dose equivalent received from radioactive material taken into the body (i.e., internal sources).

Nondispersible radioactive material	Radioactive materials packaged or contained in such a way that there is minimal potential for contamination spread. Following are examples of nondispersible material: • Dispersible radioactive materials contained in at least two barriers, one of which has structural integrity (e.g., a can with a pressure fit seal, a polyethylene jar with a screw cap, or a glass vial with a tight-fitting lid). Appropriate primary and secondary containment will vary, depending on the chemical and physical form of the material and where it is to be used or stored. • Bulk radioactive material such as machined uranium parts. If the material is likely to become significantly oxidized, it should be treated as dispersible. • Coated (painted) surfaces that seal the radioactive contaminant below the paint layer. • A sealed source (see specific definition). The ES&H Team health physicist is responsible for determining if materials should be treated as dispersible or nondispersible.
Nonradiological work	Work not involving radioactive materials or radiation-producing equipment (e.g., emptying regular waste cans, sweeping floors, and conducting other routine cleaning services). Nonradiological work can be conducted in a radioactive materials area (RMA), but all work conducted in a posted Radiation Area or Contamination Area is considered "radiological work."
Personal protective equipment (PPE)	Clothing or equipment worn by workers to prevent or minimize radiation contamination or exposure (e.g., coveralls, lab coats, anticontamination clothing, hoods, gloves, shoe covers, and respirators).
Radiation Area	Any area, accessible to individuals, where radiation levels could result in an individual receiving a deep dose equivalent exceeding 0.005 rem (5 millirem) in one hour at 30 cm from the source or from any surface that the radiation penetrates.

Radioactive material	Functionally defined at LLNL as either • Material that emits alpha, beta, gamma, or neutron radiation and contains 1 nCi or more of radioactivity. • Items with surface activity levels exceeding those specified in Appendix D. **Note:** These definitions are to be used for the purpose of radiological safety and to determine the applicability of 10 CFR 835. They DO NOT define "radioactive material" for the purpose of offsite transportation or radioactive waste disposal. (See *Criteria and Procedures for the Certification of Nonradioactive Hazardous Waste*, UCRL-AR-109988, for the definition of radioactive waste.)
Radioactive material transportation	The movement of radioactive material by aircraft, rail, vessel, or highway vehicle when such movement is subject to DOT regulations or DOE orders that govern such movements. Radioactive material transportation does not include preparation or packaging of material for transportation, monitoring required by Rule, storage of material awaiting transportation, or application of markings and labels required for transportation.
Radioactive Materials Area (RMA)	Any area within a controlled area, accessible to individuals, where items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in Appendix E.
Radioactive Materials Management Area (RMMA)	An area where dispersible radioactive materials are handled and there is the possibility of generating mixed waste (hazardous and radioactive).
Radiological Area	Any area within a controlled area defined as a Radiation Area, High Radiation Area, Very High Radiation Area, Contamination Area, High Contamination Area, or Airborne Radioactivity Area.

Radiological Buffer Area	An area where radiation or contamination may exist at levels below those that would require posting as a Radiation or Contamination Area. This area designation is NOT required by 10 CFR 835 but is useful for delineating where area conditions or PPE requirements change either inside or outside an RMA.
Radiological work	Work with any form of radioactive materials (i.e., dispersible, nondispersible, or waste), any type of work in a Contamination Area or Radiation Area, or work with radiation-generating devices (RGDs). Document 20.3, "LLNL Radiological Safety Program for Radiation-Generating Devices," in the *ES&H Manual* defines RGDs and the associated safety program. Observation of an activity does not constitute radiological work if the observer is at a sufficient distance from that activity to protect him/her from potential hazards.
Radiological work area	A general term used in this document to refer to an RMA; a discrete radioactive material-handling or storage area within an RMA; or a Type I, II, or III workplace.
Real-time air monitoring	Measurement of the concentrations or quantities of airborne radioactive materials on a continuous basis.
Respiratory protective device	An apparatus, such as a respirator, worn by an individual to reduce the intake of airborne radioactive material.
RMA	See "Radioactive Materials Area."
RMMA	See "Radioactive Materials Management Area."
Safety plan	A management-approved safety document that describes the hazards and the applicable controls for a particular work activity.

Sealed radioactive source	A radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of nonradioactive material, or firmly fixed to a nonradioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material. Sealed radioactive sources do not include reactor fuel elements, nuclear explosive devices, and radioisotope thermoelectric generators. See the definition of "accountable sealed radioactive source." **Note:** Sealed sources that meet "special form" criteria (including documentation) established by either American National Standards Institute (ANSI) or DOT may qualify for exclusion from certain facility inventory requirements established for compliance with DOE Order 1027.92, 1997. Special-form sealed sources are typically more recently purchased sources that are double encapsulated in stainless steel.
Shall	A mandatory requirement. Exemptions from contractual and regulatory requirements are obtained through the process described in Document 2.3, "LLNL Exemption Process," in the *ES&H Manual*.
Should	A recommended practice. Can also indicate a desirable or best-management practice. Written justification for declining to implement a "should" statement is not required.
Source leak test	A test to determine if a sealed radioactive source is leaking radioactive material.
Type 0 workplace	A workplace that does not provide any specific radiological protection to the worker (e.g., a storage cabinet). Such workplaces are appropriate where nondispersible radioactive materials are handled or stored.
Type I workplace	A workplace that provides minimal contamination control and does not provide a barrier between the worker and the material (e.g., a laboratory benchtop). Such workplaces are only appropriate for low-hazard operations where it is unlikely that a worker would incur an internal uptake.

Type II workplace	A workplace that provides one barrier between the worker and the material (e.g., a chemical fume hood). Such workplaces are appropriate for moderate-hazard operations where, without the proper controls, workers could incur a low-to-moderate internal uptake (e.g., up to a few rem CEDE).
Type III workplace	A workplace that provides two barriers between the worker and the material (e.g., a HEPA-filtered glove box). Such workplaces are appropriate for high-hazard operations where, without the proper controls, workers could incur a significant internal uptake (i.e., a dose greater than the legal limits).
Ventilated enclosure	A device that moves air away from the worker with a typical lineal face velocity of 100 ft/min (±20%) through any normal opening in the work enclosure (see Document 12.4 in the *ES&H Manual* for further details). Some ventilated enclosures are designed to protect the product, rather than the worker; others provide minimal worker protection (e.g., bio-safety cabinets, laminar flow hoods). Therefore, the ES&H Team health physicist, in conjunction with the industrial hygienist, shall evaluate ventilated enclosures to determine their effectiveness.
Very High Radiation Area	Any area, accessible to individuals, where radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads in one hour at 1 m from the source or from any surface that the radiation penetrates.
Whole body	For the purposes of external exposure, head, trunk (including male gonads), arms (above and including the elbow), or legs (above and including the knee).

Appendix B

Summary of Controls

Table B-1 contains a summary of work controls for areas where dispersible and nondispersible materials are used. If these controls are impractical or too costly to implement, programs should contact their ES&H Team health physicist, who may determine appropriate alternate means of achieving a commensurate level of safety. Deviations from these controls, as well as additional controls, shall be documented in the applicable safety plan.

Table B-1. Controls for work involving dispersible and nondispersible materials. An "R" indicates a required control. A "V" indicates that the control may vary depending on the operation. A "—" indicates not applicable. Deviations from these controls shall be approved by the ES&H Team health physicist.

Controls	Workplaces			
	Type 0[a]	Type I[b]	Type II[b]	Type III[b]
Facility				
• Adequate airflow in room (requires evaluation by the ES&H health physicist or industrial hygienist).	—	R	R	R
• Smooth and impermeable floors and work surface.	—	R	R	R
• Metal cabinets, drawers, or enclosures for storing radioactive materials.	R	R	—	—
• One barrier between the material and the worker's breathing zone. Note: Operations likely to breach a barrier require an additional barrier.	—	—	R	—
• Two barriers between the material and the worker's breathing zone. Note: Operations likely to breach the first or second barrier require an additional barrier.	—	—	—	R
• A ventilation system that maintains the RMA at negative pressure with respect to nonradioactive work areas (e.g., the hall).	—	—	R	R
• HEPA-filtered exhaust ventilation for the enclosure.	—	—	V	R
• HEPA-filtered exhaust ventilation for the room or facility.	—	—	V	R
• Survey conducted by the ES&H Team prior to the free release of items suspected of being contaminated (except where noted otherwise).	R	R	R	R

Table B-1. Controls for work involving dispersible and nondispersible materials. An "R" indicates a required control. A "V" indicates that the control may vary depending on the operation. A "—" indicates not applicable. (cont'd.)

Controls	Workplaces			
	Type 0[a]	Type I[b]	Type II[b]	Type III[b]
Workplace				
• Periodic contamination survey of work surfaces.	R	R	R	R
• Periodic sampling for airborne radioactivity (done by the ES&H Team).	—	—	V	R
• Continuous monitoring for airborne radioactivity (done by the ES&H Team).	—	—	—	R
• Segregation of solid and liquid radioactive and hazardous waste.	R	R	R	R
• Isolation from work areas with low-potential hazard operations.	—	—	—	R
• Equipment for monitoring workers leaving the work area.	—	V	V	R
• Provisions for safely introducing or removing material from the enclosure.	—	—	—	R
Personnel				
• Buttoned laboratory coat and gloves approved by the ES&H Team.	—	R	R	R
• Shoe covers.	—	V	V	V
• Periodic contamination monitoring of hands and clothes.	—	R	R	R
• Participation in a bioassay program, as applicable.	—	V	V	R
Administrative				
• Course HS6010, "Radiological Worker."	R			
• Course HS63xx, (e.g., "Radioactive Material Handling" or one of the contamination control courses).	—	R	R	R
• Course HS6390, "Glovebox Safety" (or equivalent).	—	—	—	R
• Radiation postings and labels.	R	R	R	R
• An FSP, OSP, or work permit.	V	R	R	R

[a] Nondispersible materials are in use.

[b] Dispersible materials are in use.

Table B-2 contains a summary of controls for radioactive materials. Important exceptions (e.g., for the acquisition of NRC generally licensed items and articles) are provided in the text of the document in the sections noted in the left-hand column.

To use this table, perform the following steps:

1. Find the quantity of radioactivity in question (e.g., 5 μCi of Pu-239).
2. Look up this value in Appendix E and determine if it is higher or lower than a Class III source (in this case, it is lower, as the Class III value for Pu-239 is 23 μ Ci).
3. Locate the amount of activity on the top line of Table B-2 (i.e., >1 μCi and < Appendix E value).
4. Follow the column straight down the table; any cell that is intersected is applicable to this source. In this example, the material would have to be
   - Acquired as radioactive material.
   - Processed by Materials Management.
   - Labeled with the trefoil symbol and isotopic information.

Presuming that the source is a sealed source, the door to the room would not need to be labeled, but the facility would be included in the triennial 10 CFR 835 internal audits. Users would not need to take HS6300, "Radioactive Material Handling," but would need to take HS6010, "Radiological Worker." Radiological workers would be allowed to transport the source onsite, but Materials Management or RHWM would have to transport the source offsite. The source would be classified as either a Class I or Class II source, as described in Section 3.10. If it is classified as a Class II source, it shall be inventoried and leak-tested semiannually.

Table B-2. Summary of radioactive material controls.

<table>
<tr><th>Topic</th><th>≥1 nCi</th><th>≥1 µCi</th><th>≥Appendix E
Class III values</th><th>≥Appendix E
Class IV values</th></tr>
<tr><td>Acquisition
(See Section 3.3)</td><td colspan="4">Acquire as radioactive material if activity is >2nCi/g;
Hazards Control RPP-SME[1] approval required, and
material shall be initially delivered to and processed by MM[2] (Building 231 Vault)</td></tr>
<tr><td>Item labeling
(See Section 3.4.5)</td><td>Label item with trefoil</td><td colspan="3">Label item with trefoil and isotopic information (i.e., isotope, activity, date)</td></tr>
<tr><td>Area posting
(See Section 3.4)</td><td></td><td colspan="2">Post Access point (the door) to dispersible material work areas</td><td>Post Access point (the door) for storage or sealed sources</td></tr>
<tr><td>Audits</td><td></td><td colspan="3">10 CFR 835.102 Internal Audits</td></tr>
<tr><td rowspan="2">Training
(See Section 3.17)</td><td colspan="4">HS-63xx (for handling dispersible material)</td></tr>
<tr><td>GERT (for handling nondispersible material)</td><td colspan="3">HS-6010 or alternate (for handling nondispersible material)
(HS-63xx is an alternate to HS-6010)</td></tr>
<tr><td rowspan="2">Transporting material
(See Section 3.9)</td><td colspan="2">Radiation workers may transport material onsite,
following Section 3.9.3</td><td colspan="2">MM/RHWM[3] required to
move material from the building</td></tr>
<tr><td colspan="4">MM/RHWM controls movement of material offsite</td></tr>
<tr><td rowspan="4">Sealed Sources
(See Section 3.10)</td><td colspan="2">Class I sealed source</td><td>Class II sealed source[4]</td><td>Class III sealed source</td><td>Class IV sealed source</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td colspan="3">Semiannual inventory and leak test of sealed sources</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Notify DOE of lost sealed sources</td></tr>
<tr><td></td><td>Metal tag required;
store in locked fire-resistant cabinet</td></tr>
</table>

[1] RPP-SME = Radiation Protection Program subject-matter expert

[2] MM = Materials Management

[3] RHWM = Radioactive and Hazardous Waste Management

[4] Administratively controlled

Appendix C

Procedures for Personnel Decontamination

Contamination of skin and personal clothing sometimes results from work with radioactive materials. It is important to remove radioactive contamination from the skin to decrease potential dose to the worker. Contaminated clothing shall be removed to prevent the spread of contamination. This appendix contains a variety of decontamination procedures that may be applied only under the direction of Hazards Control or Health Services.

In cases where a worker is contaminated and seriously injured, lifesaving measures ALWAYS take precedence over contamination control or decontamination efforts. Field decontamination should NOT be attempted if an open wound is contaminated, or if the injury may be complicated by the decontamination effort. Immediately call 911 to get help in these situations.

Where injuries are less serious, field decontamination or containment can significantly minimize the spread of contamination and make the medical response much easier. The injury and the nature of the contamination will govern the degree of decontamination that is to be performed on injured persons before they are transported to Health Services.

C.1 Removal of Clothing

Contaminants often lodge onto clothing; thus, a quick way to decontaminate someone is to remove the contaminated clothing. Remove clothes as follows:

1. If possible, have the person stand in a large plastic bag. Remove the outer contaminated clothing and leave it in the bag. Have the person step out of the bag and put on clean clothing (e.g., coveralls).

OR

2. If the person is unconscious or injured in such a way that movement may aggravate the injuries, cut away the clothing, taking care not to allow the contaminant to enter any wounds. Provide clean clothing (e.g., coveralls) or wrap the person in a blanket prior to transport to Health Services.

C.2 Transporting Injured, Contaminated Workers to Health Services

If contaminated clothing cannot be removed or if the skin is contaminated, wrap or contain the contaminated areas prior to transporting the individual to Health Services—IF this action will not aggravate the injury or cause a significant delay in obtaining critical treatment.

To wrap or contain the contaminated area,

1. Place clean clothing (e.g., coveralls or a laboratory coat, gloves, and shoe covers) over the contaminated skin or clothing.

OR

2. Place the contaminated area (e.g., an arm or leg) in a bag, loosely securing the bag with tape.

OR

3. Place gauze or blankets over the contaminated area.

C.3 Decontamination of Skin

Any procedure that removes a contaminant from the skin without causing tissue injury may be used for personnel decontamination. It is important to not damage tissue because damaged tissue provides contaminants an easy path into the bloodstream. Complexing agents (e.g., ammonium citrate) and solvents (e.g., alcohol or acetone) are absorbed readily through the skin and can carry a contaminant to the bloodstream. Irritated tissue and increased absorption rates can be more hazardous than leaving radioactivity on the outer layer of skin and waiting for natural erosion of the skin to accomplish decontamination.

From a radiation-dose standpoint, decontamination of the skin is satisfactory if the remaining dose rate to the underlying live tissue is less than 1 mrem/h. This level is achieved when beta/gamma emitters are reduced to approximately 200 disintegrations per minute (dpm)/cm^2 (~800 counts per minute (cpm)/probe area if using an Eberline E-120 with an HP-210 [pancake] probe) and alpha emitters to about 20 dpm/cm^2 (~1000 cpm/probe area if using an LLNL "Blue Alpha" meter).

> **Note:** This assumes that the radioactive material penetrates the skin to a sufficient depth to allow the alpha particles to irradiate the basal layer of the skin.

It is preferable, however, to reduce the contamination to as close as possible to an undetectable level (measured by portable survey instruments) without undue irritation of the skin.

Decontamination is simplified if the cleaning procedure prevents the spread of contaminants to other parts of the body. Therefore, if there is only local contamination, local treatment is preferable to a shower. Decontamination showers—located in Buildings 151, 251, 332, and at Health Service (Building 663)—should be used when large areas of the body are contaminated.

The person who performs the decontamination should wear protective clothing and impermeable gloves to prevent transfer of the contaminant to his/her body. All materials used during the decontamination process should be considered contaminated and disposed of as radioactive waste.

The mildest form of effective decontamination should be used whenever possible. Following are a variety of skin decontamination techniques that should be used in the order presented.

C.3.1 Rinse with Water

Rinsing the skin with water may remove the contaminant by diluting soluble material and by "floating" soluble and insoluble material. Because only small amounts of water can make contact with the contaminant at any given instant, water is most effectively used in small quantities over extended periods.

1. To decontaminate the skin,
    a. Gently rub the area with wet absorbent paper or gauze pads; repeat the process several times with clean pads. This method works for both soluble and insoluble materials.

OR

    b. Rinse the area with a fine stream of water from a wash bottle. This method is particularly effective for soluble contaminants.

OR

    c. Flood the skin with water for contamination with corrosive chemicals.
2. Survey the contaminated area. If the contaminant is an alpha emitter, dry the area completely to avoid masking the alpha radiation with water.
3. Repeat steps 1 and 2 until either decontamination is accomplished or if no decrease in radioactivity is observed after two consecutive attempts.

C.3.2 Wash with Water and Mild Detergent

If rinsing with water does not sufficiently decontaminate the skin, wash the affected area with water and a mild detergent.

1. To remove contaminants using detergents,
    a. Gently rub a wet pad on soap and then on the contaminated area.

OR

b. Moisten a pad with a 5% detergent solution and gently rub the contaminated area.

Note: If more soap or detergent is needed, use a fresh pad. The soap or detergent is removed by successive wiping with wet pads. DO NOT use alcohol, acetone, or other solvents, as these materials tend to increase absorption through the skin.

2. Survey the contaminated area. If the contaminant is an alpha emitter, dry the area completely to avoid masking the alpha radiation with water.
3. Repeat steps 1 and 2 until decontamination is accomplished or until no decrease in radioactivity is observed after consecutively washing the area twice.

C.3.3 Scrub with a Brush and Mild Detergent

When simple washing with detergent does not decontaminate the skin, use of a soft bristle brush may release the contaminant. Apply the technique in Section C.3.2 but replace the paper or gauze pads with a soft bristle brush.

C.3.4 Trim Contaminated Nails or Callused Skin

If contamination persists around fingernails or calluses, trimming the nail or callus may effectively remove the contaminant. Be careful not to trim too closely, as damaged skin provides a direct pathway for contaminants to enter the bloodstream.

C.3.5 Treatment with Chemicals

If the techniques previously described do not work, it may be necessary to use chemical methods to remove the contaminant from the skin. Obtain approval from Health Services and then

1. Moisten the contaminated area with water. Sprinkle a few crystals of potassium permanganate on the affected area. Roll the crystals across the contaminated area until it is stained.
2. Add water as needed to keep the crystals dissolving.
3. When the entire area is stained, remove the remaining crystals with moistened paper or gauze pads.
4. Sprinkle a small amount of sodium bisulfite powder on the stained area and spread it around.
5. Add more water and sodium bisulfite as needed until the brown stain is removed.
6. Rinse the area with wet swabs, absorbent paper, or gauze pads.

7. After drying, check the area with a survey meter to determine if the decontamination was successful.

DO NOT repeat this procedure as it will damage the outer layer of the skin and irritate living tissue.

C.3.6 Natural Erosion

Regardless of the method used, stop decontamination efforts if skin damage appears imminent. If contamination has not been reduced to a dose rate below 10 mrem/h, Health Services will evaluate further decontamination efforts (e.g., debridement and excision). More typically, the contaminant is allowed to slough off through the normal skin aging process.

Note: 10 mrem/h is equivalent to ~2000 dpm/cm^2 for beta emitters (8000 cpm/probe area if using an Eberline E-120 with an HP-210 [pancake] probe), or 200 dpm/cm^2 for alpha emitters (~10,000 cpm/probe area if using an LLNL "Blue Alpha" meter).

If it becomes impractical to reduce a contaminant to a dose rate below 1 mrem/h, then protect the area as follows and allow natural erosion to occur:

1. Cover the contaminated area with a gauze bandage, then cover the bandage with a loose-fitting glove or a piece of plastic. Avoid placing nonbreathing coverings (e.g., surgeon's gloves or adhesive tape) directly on body surfaces since the accumulation of perspiration encourages absorption through the skin. Absorbent material placed between the skin and the nonbreathing covering may help remove insoluble contaminants such as PuO_2.
2. Keep the bandage in place to avoid the spread of contaminants to other surfaces.
3. Change bandages daily at Health Services or Hazards Control. Check if natural erosion of the outer skin has released the contaminant. Continue to wear the covering until the contaminant is removed or until directed otherwise by Hazards Control or Health Services.

C.4 Decontamination of Hair

The procedure for hair decontamination is very similar to those previously described for skin decontamination. If only a small portion of the hair is contaminated, attempt to decontaminate it with water and mild detergent. If the contaminant cannot be removed and the dose rate exceeds 5 mrem/h, obtain permission from the worker to remove the contaminated hair with scissors or a razor.

Note: 5 mrem/h is equivalent to ~1000 dpm/cm^2 for beta emitters (4000 cpm/probe area if using an Eberline E-120 with an HP-210 [pancake] probe), or 100 dpm/cm^2 for alpha emitters (~5000 cpm/probe area if using an LLNL "Blue Alpha" meter).

To decontaminate a large portion of hair,

1. Remove the individual's outer clothing and have him/her put on either coveralls or a lab coat and surgeon's gloves.
2. Wrap a towel across the individual's neck and face to prevent the flow of fluid from the hair to other parts of the body.
3. Seat the individual with his/her head bent over a basin or pail.
4. Either wet the hair with water and apply soap, or wet the hair with a 5% solution of mild detergent. Work the detergent into the hair thoroughly or allow the person to wash his/her own hair.
5. Rinse the lather from the hair with a small stream of water. Catch all rinse water in a basin or pail.
6. Towel-dry the hair and check it with a survey meter. Also check the worker's face and neck to be sure the contamination has not spread.
7. If the contaminant persists, repeat steps 4–6 once or twice more.
8. If contamination persists and exceeds a dose rate of 5 mrem/h, obtain permission from the individual to remove the contaminated hair with scissors. Bandaging the uncut hair with a close-fitting cotton cap can be attempted, but this method may take too much time as hair erosion occurs much slower than skin erosion.

Note: 5 mrem/h is equivalent to ~1000 dpm/cm^2 for beta emitters (4000 cpm/probe area if using an Eberline E–120 with an HP-210 [pancake] probe), or 100 dpm/cm^2 for alpha emitters (~5000 cpm/probe area if using an LLNL "Blue Alpha" meter).

C.5 Medical Procedures

When a contaminated object penetrates the skin, radioactive material may be imbedded in a localized area in or around the wound site. Irrigation, debridement, or surgical removal of the material may effectively reduce the ultimate dose from thousands of rem to a few mrem. Surgical procedures shall be directed or coordinated through Health Services and may be carried out only with the permission of the patient.

C.5.1 Surgical Removal

Debridement and excision involve the surgical removal of tissue in or near a wound and are performed under sterile conditions with an anesthetic. Typically, only small amounts of skin and muscle tissue are removed, and the risk to the worker is not significant.

C.5.2 Chelation

Timely administration of chelating agents can significantly reduce the radiation dose received from an intake of transuranic elements such as plutonium, americium, and curium. Chelating agents are chemicals that combine with metal ions to form stable and soluble molecules. Reaction with transuranic elements in the bloodstream enhances the body's ability to excrete these elements via the urine. The chelating agent currently recommended for use with plutonium is diethylene triamine penta acetic acid, or DTPA, in the form of a calcium (Ca-DTPA) or zinc (Zn–DTPA) compound.

The chelating agent DTPA can significantly increase the rate of excretion of transuranic elements from the body, thereby significantly lowering the total dose received. The effectiveness of DTPA treatment depends greatly upon the route of intake, the chemical and physical form of the material, and the time and duration of the DTPA treatment(s). Dose reductions from 10 to 90% have been achieved for wound and burn cases, and dose reductions of up to 30% have been achieved for inhalation intakes.

To be most effective, the initial administration of DTPA should be given as soon as possible after the suspected intake and preferably within one hour. The normal method of administration of DTPA is via intravenous injection or inhalation of an aerosol. Early administration allows the DTPA to work while the largest quantity of material is still in the bloodstream. DTPA has been used successfully on hundreds of people for over 30 years. However, since it has little commercial use outside the plutonium-handling community, DTPA is still categorized as an "Investigational New Drug" by the Food and Drug Administration. As such, use of DTPA is carefully monitored and controlled, and the patient shall give specific medical consent.

Administration of DTPA is not expected to cause any serious side effects or risks. Some individuals have reported minor temporary side effects such as nausea, vomiting, diarrhea, chills, fever, itching and muscle cramps after multiple administrations. No serious toxic effects have been observed in more than 500 patients receiving more than 3,000 injections. One patient (not from LLNL) received more than 400 doses of DTPA in a four-year period without adverse effects.

For more information on any of these procedures, contact the ES&H Team or Health Services.

Appendix D

Surface Contamination Values

The information in this appendix is identical to that in 10 CFR 835, Appendix D, and is to be used in identifying and posting Contamination and High Contamination Areas and identifying the need for surface contamination monitoring and control. These values are also used to identify when items or articles with surface contamination shall be controlled as radioactive material.

Table D-1. Surface contamination values[1] in dpm/100 cm^2.

Radionuclide	Removable[2,4]	Total (fixed plus removable)[2,3]
U-nat, U-235, U-238, and associated decay products	1,000 (alpha)	5,000 (alpha)
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I–125, I-129	20	500 (300 for release to the public)
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above[5]	1,000	5,000
Tritium and tritiated compounds[6]	10,000	NA

1 The values in this appendix, with the exception noted in footnote 6, apply to radioactive contamination deposited on, but not incorporated into the interior or matrix of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides apply independently.

2 As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

3 The levels may be averaged over 1 m^2 provided that the maximum surface activity in any area of 100 cm^2 is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if, from measurements of a representative number of sections, it is determined that (1) the average contamination level exceeds the applicable value; or (2) the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds three times the applicable value.

4 The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. Note: The use of dry material may not be appropriate for tritium. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area shall be based on the actual area, and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

5 This category of radionuclides includes mixed fission products, including the Sr–90 that is present in them. It does not apply to Sr–90 that has been separated from the other fission products or mixtures where the Sr–90 has been enriched.

6 Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a "Total" value does not apply.

Appendix E

Values for Establishing Sealed Radioactive Source Accountability and Radioactive Materials Posting and Labeling Requirements

The Class III values listed in Table E-1 shall be used to

- Identify the threshold for accountable sealed radioactive sources (see Section 3.10).
- Establish the need for posting radioactive material areas (see Section 3.4).
- Identify the quantity of material that needs to be transported onsite by Materials Management (see Section 3.9).

Any alpha-emitting radionuclide not listed in this table and mixtures of alpha emitters of unknown composition have a value of 10 μCi. Any radionuclide, other than alpha-emitting radionuclides, not listed in the table and mixtures of beta emitters of unknown composition have a value of 100 μCi.

Note: The activity based Class III activity thresholds are identical to those provided in 10 CFR 835 Appendix E. LLNL has provided the mass equivalent values for convenience.

The Class IV values listed in Table E-1 pertain to storage and labeling of sealed radioactive sources only.

Note: For a combination of radionuclides in known amounts, derive the value for the combination as follows: determine, for each radionuclide in the combination, the ratio between the quantity present in the combination and the value otherwise established for the specific radionuclide when not in combination. If the sum of such ratios for all radionuclides in the combination exceeds unity (1), then the accountability criterion has been exceeded.

Table E-1. The Class III values establish the threshold for sealed radioactive source accountability, radioactive material area posting, and onsite transportation. (Note: The data in this table are listed in alphabetical order by nuclide.)

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Ac-227	1.5	2.1×10^{8}	7.5×10^{1}	1.0×10^{-6}
Ag-105	2.1×10^{6}	6.9×10^{-5}	1.1×10^{8}	3.5×10^{-3}
Ag-108m	1.8×10^{1}	6.9×10^{-7}	9.0×10^{2}	3.5×10^{-5}
Ag-110m	2.2×10^{1}	4.6×10^{-9}	1.1×10^{3}	2.3×10^{-7}
Al-26	1.6×10^{1}	8.3×10^{-4}	8.0×10^{2}	4.2×10^{-2}
Am-241	2.3×10^{1}	6.7×10^{-6}	1.2×10^{3}	3.3×10^{-4}
Am-242m	2.4×10^{1}	2.5×10^{-6}	1.2×10^{3}	1.2×10^{-4}
Am-243	2.3×10^{1}	1.2×10^{-4}	1.2×10^{3}	5.8×10^{-3}
As-73	5.4×10^{2}	2.4×10^{-8}	2.7×10^{4}	1.2×10^{-6}
Au-195	4.8×10^{2}	1.3×10^{-7}	2.4×10^{4}	6.6×10^{-6}
Ba-133	5.2×10^{1}	2.1×10^{-7}	2.6×10^{3}	1.0×10^{-5}
Be-10	2.8×10^{4}	1.3	1.4×10^{6}	6.3×10^{1}
Be-7	3.2×10^{3}	9.1×10^{-9}	1.6×10^{5}	4.6×10^{-7}
Bi-207	1.7×10^{1}	3.1×10^{-7}	8.5×10^{2}	1.6×10^{-5}
Bi-208	1.5×10^{1}	3.2×10^{-3}	7.5×10^{2}	1.6×10^{-1}
Bi-210m	1.3×10^{3}	2.3	6.5×10^{4}	1.1×10^{2}
Bk-247	1.7×10^{1}	1.6×10^{-5}	8.5×10^{2}	8.1×10^{-4}
Bk-249	7.2×10^{3}	4.4×10^{-6}	3.6×10^{5}	2.2×10^{-4}
C-14	4.8×10^{6}	1.1	2.4×10^{8}	5.4×10^{1}
Ca-41	7.4×10^{6}	8.7×10^{1}	3.7×10^{8}	4.4×10^{3}
Ca-45	1.5×10^{6}	8.4×10^{-5}	7.5×10^{7}	4.2×10^{-3}
Cd-109	1.6×10^{2}	6.2×10^{-8}	8.0×10^{3}	3.1×10^{-6}
Cd-113m	6.5×10^{3}	2.8×10^{-5}	3.3×10^{5}	1.4×10^{-3}
Cd-115m	1.0×10^{4}	3.9×10^{-7}	5.0×10^{5}	2.0×10^{-5}
Ce-139	2.4×10^{2}	3.5×10^{-8}	1.2×10^{4}	1.8×10^{-6}
Ce-141	2.4×10^{3}	8.4×10^{-8}	1.2×10^{5}	4.2×10^{-6}
Ce-144	1.5×10^{3}	4.7×10^{-7}	7.5×10^{4}	2.4×10^{-5}
Cf-248	2.0×10^{2}	1.3×10^{-7}	1.0×10^{4}	6.3×10^{-6}
Cf-249	1.7×10^{1}	4.1×10^{-6}	8.5×10^{2}	2.1×10^{-4}

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Cf-250	3.8×10^{1}	3.5×10^{-7}	1.9×10^{3}	1.7×10^{-5}
Cf-251	1.7×10^{1}	1.1×10^{-5}	8.5×10^{2}	5.4×10^{-4}
Cf-252	6.4×10^{1}	1.2×10^{-7}	3.2×10^{3}	5.9×10^{-6}
Cf-254	3.4×10^{1}	4.0×10^{-9}	1.7×10^{3}	2.0×10^{-7}
Cl-36	4.6×10^{5}	1.4×10^{1}	2.3×10^{7}	7.0×10^{2}
Cm-241	6.8×10^{4}	4.1×10^{-6}	3.4×10^{6}	2.1×10^{-4}
Cm-242	5.8×10^{2}	1.7×10^{-7}	2.9×10^{4}	8.7×10^{-6}
Cm-243	3.3×10^{1}	6.4×10^{-7}	1.7×10^{3}	3.2×10^{-5}
Cm-244	4.0×10^{1}	4.9×10^{-7}	2.0×10^{3}	2.5×10^{-5}
Cm-245	2.2×10^{1}	1.3×10^{-4}	1.1×10^{3}	6.4×10^{-3}
Cm-246	2.2×10^{1}	7.1×10^{-5}	1.1×10^{3}	3.6×10^{-3}
Cm-247	2.4×10^{1}	2.6×10^{-1}	1.2×10^{3}	1.3×10^{1}
Cm-248	6.0	1.4×10^{-3}	3.0×10^{2}	7.0×10^{-2}
Cm-250	1.1	7.5×10^{-6}	5.5×10^{1}	3.7×10^{-4}
Co-56	4.0×10^{1}	1.4×10^{-9}	2.0×10^{3}	6.8×10^{-8}
Co-57	2.3×10^{2}	2.7×10^{-8}	1.2×10^{4}	1.4×10^{-6}
Co-58	1.4×10^{2}	4.4×10^{-9}	7.0×10^{3}	2.2×10^{-7}
Co-60	1.8×10^{1}	1.6×10^{-8}	9.0×10^{2}	8.0×10^{-7}
Cs-134	2.7×10^{1}	2.1×10^{-8}	1.4×10^{3}	1.0×10^{-6}
Cs-135	2.2×10^{6}	1.9×10^{3}	1.1×10^{8}	9.5×10^{4}
Cs-137	6.0×10^{1}	6.9×10^{-7}	3.0×10^{3}	3.4×10^{-5}
Dy-159	4.1×10^{6}	7.2×10^{-4}	2.1×10^{8}	3.6×10^{-2}
Es-254	6.3×10^{1}	3.4×10^{-8}	3.2×10^{3}	1.7×10^{-6}
Es-255	4.6×10^{4}	3.6×10^{-6}	2.3×10^{6}	1.8×10^{-4}
Eu-148	7.0×10^{5}	4.3×10^{-5}	3.5×10^{7}	2.2×10^{-3}
Eu-149	5.3×10^{6}	5.6×10^{-4}	2.7×10^{8}	2.8×10^{-2}
Eu-152	3.1×10^{1}	1.8×10^{-7}	1.6×10^{3}	8.8×10^{-6}
Eu-154	3.1×10^{1}	1.2×10^{-7}	1.6×10^{3}	5.9×10^{-6}
Eu-155	3.7×10^{2}	8.0×10^{-7}	1.9×10^{4}	4.0×10^{-5}
Fe-55	3.7×10^{6}	1.5×10^{-3}	1.9×10^{8}	7.7×10^{-2}
Fe-59	2.0×10^{2}	4.0×10^{-9}	1.0×10^{4}	2.0×10^{-7}
Fe-60	1.3×10^{4}	2.2×10^{-1}	6.5×10^{5}	1.1×10^{1}
Fm-257	4.3×10^{2}	8.5×10^{-8}	2.2×10^{4}	4.3×10^{-6}

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Gd-146	2.6×10^{5}	1.4×10^{-5}	1.3×10^{7}	7.0×10^{-4}
Gd-148	3.0×10^{1}	1.2×10^{-6}	1.5×10^{3}	5.8×10^{-5}
Gd-151	1.1×10^{6}	1.5×10^{-4}	5.5×10^{7}	7.6×10^{-3}
Gd-153	2.1×10^{2}	6.0×10^{-8}	1.1×10^{4}	3.0×10^{-6}
Ge-68	5.7×10^{2}	8.5×10^{-8}	2.9×10^{4}	4.3×10^{-6}
H-3 (elemental)	1.6×10^{8}	1.7×10^{-2}	8.0×10^{9}	8.3×10^{-1}
Hf-172	3.1×10^{4}	2.8×10^{-5}	1.6×10^{6}	1.4×10^{-3}
Hf-175	1.8×10^{6}	1.7×10^{-4}	9.0×10^{7}	8.4×10^{-3}
Hf-178m	4.1×10^{3}	6.3×10^{-5}	2.1×10^{5}	3.2×10^{-3}
Hf-181	3.5×10^{2}	2.1×10^{-8}	1.8×10^{4}	1.0×10^{-6}
Hf-182	3.0×10^{3}	1.4×10^{1}	1.5×10^{5}	6.9×10^{2}
Hg-194	3.5×10^{4}	8.4×10^{-3}	1.8×10^{6}	4.2×10^{-1}
Hg-203	4.9×10^{2}	3.5×10^{-8}	2.5×10^{4}	1.8×10^{-6}
Ho-166m	2.2×10^{1}	1.2×10^{-5}	1.1×10^{3}	6.1×10^{-4}
I-125	3.5×10^{2}	2.0×10^{-8}	1.8×10^{4}	1.0×10^{-6}
I-129	1.8×10^{2}	1.0	9.0×10^{3}	5.1×10^{1}
In-114m	7.8×10^{2}	3.4×10^{-8}	3.9×10^{4}	1.7×10^{-6}
Ir-192	1.4×10^{2}	1.5×10^{-8}	7.0×10^{3}	7.6×10^{-7}
Ir-192m	2.6×10^{4}	3.4×10^{-3}	1.3×10^{6}	1.7×10^{-1}
Ir-194m	2.7×10^{1}	6.9×10^{-9}	1.4×10^{3}	3.4×10^{-7}
K-40	2.8×10^{2}	4.0×10^{1}	1.4×10^{4}	2.0×10^{3}
La-137	1.1×10^{5}	2.5	5.5×10^{6}	1.3×10^{2}
Lu-173	4.4×10^{5}	2.9×10^{-4}	2.2×10^{7}	1.5×10^{-2}
Lu-174	2.5×10^{5}	4.0×10^{-4}	1.3×10^{7}	2.0×10^{-2}
Lu-174m	3.9×10^{5}	7.4×10^{-5}	2.0×10^{7}	3.7×10^{-3}
Lu-177m	5.8×10^{1}	1.3×10^{-8}	2.9×10^{3}	6.3×10^{-7}
Md-258	6.0×10^{2}	6.5×10^{-8}	3.0×10^{4}	3.3×10^{-6}
Mn-53	2.0×10^{7}	1.1×10^{4}	1.0×10^{9}	5.5×10^{5}
Mn-54	6.5×10^{1}	8.4×10^{-9}	3.3×10^{3}	4.2×10^{-7}
Mo-93	7.7×10^{1}	7.0×10^{-5}	3.9×10^{3}	3.5×10^{-3}
Na-22	1.9×10^{1}	3.0×10^{-9}	9.5×10^{2}	1.5×10^{-7}
Nb-91	7.0×10^{1}	1.2×10^{-5}	3.5×10^{3}	6.1×10^{-4}
Nb-91m	3.6×10^{2}	1.6×10^{-8}	1.8×10^{4}	7.8×10^{-7}

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Nb-92	1.8×10^{1}	1.6×10^{-1}	9.0×10^{2}	8.0
Nb-93m	4.4×10^{2}	1.6×10^{-6}	2.2×10^{4}	7.8×10^{-5}
Nb-94	2.3×10^{1}	1.2×10^{-4}	1.2×10^{3}	6.1×10^{-3}
Nb-95	3.4×10^{2}	8.7×10^{-9}	1.7×10^{4}	4.3×10^{-7}
Ni-59	7.5×10^{6}	9.3×10^{1}	3.8×10^{8}	4.6×10^{3}
Ni-63	3.2×10^{6}	5.4×10^{-2}	1.6×10^{8}	2.7
Np-235	1.2×10^{2}	8.6×10^{-8}	6.0×10^{3}	4.3×10^{-6}
Np-236	2.2×10^{1}	2.2×10^{-3}	1.1×10^{3}	1.1×10^{-1}
Np-237	1.9×10^{1}	2.7×10^{-2}	9.5×10^{2}	1.3
Os-185	1.4×10^{2}	1.9×10^{-8}	7.0×10^{3}	9.3×10^{-7}
Os-194	1.5×10^{4}	4.9×10^{-5}	7.5×10^{5}	2.4×10^{-3}
Pa-231	7.8	1.6×10^{-4}	3.9×10^{2}	8.2×10^{-3}
Pb-202	1.0×10^{5}	3.0	5.0×10^{6}	1.5×10^{2}
Pb-205	9.1×10^{1}	7.9×10^{-1}	4.6×10^{3}	4.0×10^{1}
Pb-210	9.2×10^{1}	1.2×10^{-6}	4.6×10^{3}	6.0×10^{-5}
Pd-107	7.8×10^{5}	1.5×10^{3}	3.9×10^{7}	7.6×10^{4}
Pm-143	1.3×10^{2}	3.8×10^{-8}	6.5×10^{3}	1.9×10^{-6}
Pm-144	2.9×10^{1}	1.2×10^{-8}	1.5×10^{3}	5.8×10^{-7}
Pm-145	2.6×10^{2}	1.9×10^{-6}	1.3×10^{4}	9.3×10^{-5}
Pm-146	4.5×10^{1}	1.0×10^{-7}	2.3×10^{3}	5.1×10^{-6}
Pm-147	2.5×10^{5}	2.7×10^{-4}	1.3×10^{7}	1.3×10^{-2}
Pm-148m	1.1×10^{2}	5.1×10^{-9}	5.5×10^{3}	2.6×10^{-7}
Po-209	6.3×10^{3}	3.8×10^{-4}	3.2×10^{5}	1.9×10^{-2}
Po-210	1.1×10^{3}	2.4×10^{-7}	5.5×10^{4}	1.2×10^{-5}
Pt-193	4.4×10^{7}	1.2	2.2×10^{9}	5.9×10^{1}
Pu-236	6.9×10^{1}	1.3×10^{-7}	3.5×10^{3}	6.5×10^{-6}
Pu-237	3.3×10^{2}	2.7×10^{-8}	1.7×10^{4}	1.4×10^{-6}
Pu-238	2.5×10^{1}	1.5×10^{-6}	1.3×10^{3}	7.3×10^{-5}
Pu-239	2.3×10^{1}	3.7×10^{-4}	1.2×10^{3}	1.8×10^{-2}
Pu-240	2.3×10^{1}	1.0×10^{-4}	1.2×10^{3}	5.0×10^{-3}
Pu-241	1.2×10^{3}	1.2×10^{-5}	6.0×10^{4}	5.8×10^{-4}
Pu-242	2.4×10^{1}	6.1×10^{-3}	1.2×10^{3}	3.1×10^{-1}
Pu-244	2.5×10^{1}	1.4	1.3×10^{3}	7.0×10^{1}

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Ra-226	1.2×10^{3}	1.2×10^{-3}	6.0×10^{4}	6.1×10^{-2}
Ra-228	2.1×10^{3}	7.7×10^{-6}	1.1×10^{5}	3.8×10^{-4}
Rb-83	9.2×10^{1}	5.0×10^{-9}	4.6×10^{3}	2.5×10^{-7}
Rb-84	2.0×10^{2}	4.2×10^{-9}	1.0×10^{4}	2.1×10^{-7}
Re-183	5.4×10^{2}	5.3×10^{-8}	2.7×10^{4}	2.6×10^{-6}
Re-184	2.6×10^{2}	1.4×10^{-8}	1.3×10^{4}	7.0×10^{-7}
Re-184m	1.5×10^{2}	3.5×10^{-8}	7.5×10^{3}	1.7×10^{-6}
Re-186m	2.8×10^{5}	2.9×10^{1}	1.4×10^{7}	1.5×10^{3}
Rh-101	2.5×10^{5}	2.3×10^{-4}	1.3×10^{7}	1.1×10^{-2}
Rh-102	8.3×10^{4}	6.9×10^{-5}	4.2×10^{6}	3.4×10^{-3}
Rh-102m	2.1×10^{5}	3.4×10^{-5}	1.1×10^{7}	1.7×10^{-3}
Ru-103	4.4×10^{2}	1.4×10^{-8}	2.2×10^{4}	6.8×10^{-7}
Ru-106	2.1×10^{4}	6.4×10^{-6}	1.1×10^{6}	3.2×10^{-4}
S-35	4.0×10^{6}	9.4×10^{-5}	2.0×10^{8}	4.7×10^{-3}
Sb-124	9.1×10^{1}	5.2×10^{-9}	4.6×10^{3}	2.6×10^{-7}
Sb-125	6.8×10^{1}	6.6×10^{-8}	3.4×10^{3}	3.3×10^{-6}
Sc-46	6.2×10^{1}	1.8×10^{-9}	3.1×10^{3}	9.2×10^{-8}
Se-75	6.4×10^{1}	4.4×10^{-9}	3.2×10^{3}	2.2×10^{-7}
Se-79	1.0×10^{6}	1.4×10^{1}	5.0×10^{7}	7.2×10^{2}
Si-32	9.9×10^{3}	1.5×10^{-4}	5.0×10^{5}	7.6×10^{-3}
Sm-145	9.1×10^{5}	3.4×10^{-4}	4.6×10^{7}	1.7×10^{-2}
Sm-146	1.2×10^{2}	5.0	6.0×10^{3}	2.5×10^{2}
Sm-151	2.5×10^{5}	9.5×10^{-3}	1.3×10^{7}	4.7×10^{-1}
Sn-113	3.1×10^{2}	3.1×10^{-8}	1.6×10^{4}	1.5×10^{-6}
Sn-119m	3.3×10^{2}	8.8×10^{-8}	1.7×10^{4}	4.4×10^{-6}
Sn-121m	8.7×10^{5}	1.6×10^{-2}	4.4×10^{7}	8.1×10^{-1}
Sn-123	1.3×10^{4}	1.6×10^{-6}	6.5×10^{5}	7.9×10^{-5}
Sn-126	1.8×10^{2}	6.3×10^{-3}	9.0×10^{3}	3.2×10^{-1}
Sr-85	1.2×10^{2}	5.1×10^{-9}	6.0×10^{3}	2.5×10^{-7}
Sr-89	2.4×10^{5}	8.3×10^{-6}	1.2×10^{7}	4.1×10^{-4}
Sr-90	7.7×10^{3}	5.6×10^{-5}	3.9×10^{5}	2.8×10^{-3}
Ta-179	1.5×10^{6}	1.4×10^{-3}	7.5×10^{7}	6.8×10^{-2}
Ta-182	7.3×10^{1}	1.2×10^{-8}	3.7×10^{3}	5.9×10^{-7}

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Tb-157	2.5×10^{3}	1.6×10^{-4}	1.3×10^{5}	8.2×10^{-3}
Tb-158	3.9×10^{4}	2.6×10^{-3}	2.0×10^{6}	1.3×10^{-1}
Tb-160	1.2×10^{2}	1.1×10^{-8}	6.0×10^{3}	5.3×10^{-7}
Tc-95m	1.3×10^{2}	5.8×10^{-9}	6.5×10^{3}	2.9×10^{-7}
Tc-97	8.1×10^{1}	5.7×10^{-2}	4.1×10^{3}	2.9
Tc-97m	3.6×10^{2}	2.3×10^{-8}	1.8×10^{4}	1.2×10^{-6}
Tc-98	2.5×10^{1}	2.9×10^{-2}	1.3×10^{3}	1.4
Tc-99	6.8×10^{6}	4.0×10^{2}	3.4×10^{8}	2.0×10^{4}
Te-121m	1.9×10^{2}	2.7×10^{-8}	9.5×10^{3}	1.4×10^{-6}
Te-123m	2.8×10^{2}	3.2×10^{-8}	1.4×10^{4}	1.6×10^{-6}
Te-125m	4.4×10^{2}	2.4×10^{-8}	2.2×10^{4}	1.2×10^{-6}
Te-127m	8.0×10^{2}	8.5×10^{-8}	4.0×10^{4}	4.2×10^{-6}
Te-129m	2.3×10^{3}	7.6×10^{-8}	1.2×10^{5}	3.8×10^{-6}
Th-228	2.9×10^{1}	3.5×10^{-8}	1.5×10^{3}	1.8×10^{-6}
Th-229	4.7	2.2×10^{-5}	2.4×10^{2}	1.1×10^{-3}
Th-230	3.1×10^{1}	1.5×10^{-3}	1.6×10^{3}	7.7×10^{-2}
Th-232	6.1	5.6×10^{1}	3.1×10^{2}	2.8×10^{3}
Ti-44	1.6×10^{2}	9.3×10^{-7}	8.0×10^{3}	4.7×10^{-5}
Tl-204	2.2×10^{4}	4.7×10^{-5}	1.1×10^{6}	2.4×10^{-3}
Tm-170	8.4×10^{3}	1.4×10^{-6}	4.2×10^{5}	7.0×10^{-5}
Tm-171	2.8×10^{4}	2.6×10^{-5}	1.4×10^{6}	1.3×10^{-3}
U-232	1.5×10^{1}	7.0×10^{-7}	7.5×10^{2}	3.5×10^{-5}
U-233	7.4×10^{1}	7.6×10^{-3}	3.7×10^{3}	3.8×10^{-1}
U-234	7.5×10^{1}	1.2×10^{-2}	3.8×10^{3}	6.0×10^{-1}
U-235	6.7×10^{1}	3.1×10^{1}	3.4×10^{3}	1.5×10^{3}
U-236	8.0×10^{1}	1.2	4.0×10^{3}	6.2×10^{1}
U-238	8.4×10^{1}	2.5×10^{2}	4.2×10^{3}	1.2×10^{4}
V-49	2.9×10^{7}	3.6×10^{-3}	1.5×10^{9}	1.8×10^{-1}
W-181	1.1×10^{3}	1.8×10^{-7}	5.5×10^{4}	9.2×10^{-6}
W-185	3.9×10^{6}	4.1×10^{-4}	2.0×10^{8}	2.1×10^{-2}
W-188	6.4×10^{4}	6.4×10^{-6}	3.2×10^{6}	3.2×10^{-4}
Y-88	3.4×10^{1}	2.4×10^{-9}	1.7×10^{3}	1.2×10^{-7}
Y-91	5.0×10^{4}	2.0×10^{-6}	2.5×10^{6}	1.0×10^{-4}

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
Yb-169	5.5×10^{2}	2.3×10^{-8}	2.8×10^{4}	1.1×10^{-6}
Zn-65	1.1×10^{2}	1.3×10^{-8}	5.5×10^{3}	6.7×10^{-7}
Zr-88	1.2×10^{2}	6.7×10^{-9}	6.0×10^{3}	3.4×10^{-7}
Zr-93	3.1×10^{4}	1.2×10^{1}	1.6×10^{6}	6.2×10^{2}
Zr-95	2.0×10^{2}	9.3×10^{-9}	1.0×10^{4}	4.7×10^{-7}

Note: The following materials are not specifically identified in 10 CFR 835, Appendix E, but are frequently used at LLNL. The following values are to be used as the threshold values for establishing sealed radioactive source accountability and radioactive material posting and labeling requirements.

Nuclide	Class III		Class IV	
	Activity (μCi)	Mass equivalent (g)	Activity (μCi)	Mass equivalent (g)
H-3 (oxide)	1.0×10^{6}	6.9×10^{-4}	5.0×10^{7}	3.4×10^{-2}
K-85	1.6×10^{4}	4.1×10^{-5}	8.0×10^{5}	2.0×10^{-3}
Depleted uranium	8.4×10^{1}	2.1×10^{2}	4.2×10^{3}	4.1×10^{4}
U-natural	8.0×10^{1}	1.2×10^{2}	4.0×10^{3}	6.0×10^{3}
U-235 enriched* (95%)	7.5×10^{1}	1.1	3.8×10^{3}	5.4×10^{1}

* Values for other enrichments vary. Contact your ES&H Team health physicist for more information.